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Comparing Cleanup Costs to Risk for Selected USAF Pump and Treat Systems: Remediating Trichloroethylene Contaminated Aquifers

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13. ABSTRACT *(Maximum 200 words)*
This paper investigates Pump and Treat (P&T) systems operating at U.S. Air Force (USAF) installations having ground water contaminated with Trichloroethylene (TCE). As part of this study, it was found that in 1997 the USAF was operating 86 P&T systems at 49 of its installations.

The EPA regulated TCE in drinking water in 1989 at a level of 5 ppb based on the results of animal bioassays. EPA established a health goal of zero and set the enforceable MCL at 5 ppb based on the feasibility of detection at the time. This study is a compilation of information on Air Force installation P&T systems to submit to the EPA's Office of Ground and Drinking Water in support of a review and possible revision of the Drinking Water Standard for TCE to be based on a scientifically sound standard rather than the current policy based standard.

Statistical forecasting was performed on 4 P&T sites to determine when operations of the P&T systems could be terminated based on the different cleanup levels of 5, 50, and 100 ppb. The statistical model algorithm was also used to forecast the lifetime excess cancer risk at the sites based on the TCE contaminant level. Cumulative costs and price to capture each gallon of TCE through time was also determined. By just considering the 4 sites the cost savings realized from raising the TCE MCL from 5 to 50 ppb would be approximately $60 million and from 5 to 100 ppb would be approximately $72 million. If the average cost savings from the 4 sites was applied to the 61 TCE sites, an estimated $0.9 billion to $1.1 billion could be saved by raising the TCE MCL to 50 ppb or 100 ppb, respectively.

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The Health Risk Assessment Branch (AFIERA/RSRE) of the Human Systems Center undertook a study concerning USAF P&T remediation systems operating at TCE contaminated groundwater sites. The study was conducted under the guidance of Dr. Elizabeth Maull, staff toxicologist for AFIERA/RSRE.

A major portion of this project involved gathering extensive amounts of data concerning the operation of P&T systems at Air Force installations. Many people assisted in supplying this data to us. Major Jeff Ogden of the Department of Defense Office of the Inspector General was a source of much of the construction and operational cost data which was derived from their project, "Evaluation of DoD Waste Site Groundwater Pump-and-Treat Operations."

Mr. John Rogers, Senior Statistician at Westat, authored a Microsoft Excel workbook program which was used to forecast aquifer contaminant concentrations. His work was essential to this project in determining P&T system operating time based on the different TCE cleanup levels of 5 ppb, 50 ppb, and 100 ppb. Captain Mahendra Kabbur, USAF, BSC, also assisted us in our use of statistics for forecasting contaminant levels. Dr. Nicholas Giardino, staff toxicologist for AFIERA/RSH, helped us in assessing our data and in portraying our findings. In addition, numerous personnel at various bases supplied us with information concerning the P&T systems at their location.

COMPARING CLEANUP COSTS TO RISKS FOR SELECTED USAF PUMP AND TREAT SYSTEMS REMEDIATING TRICHLOROETHYLENE CONTAMINATED AQUIFERS

EXECUTIVE SUMMARY

In the United States, from 300,000 to 400,000 contaminated sites are scheduled for cleanup in the coming decades, at an estimated total cost as high as $500 billion to $1 trillion (National Research Council, 1997). Pump and Treat (P&T) remediation systems are in place, or will be in the future, at many of these sites to remediate contaminants that have migrated into the groundwater. Many are questioning the ability of conventional technologies such as P&T to remediate contaminated aquifers.

This study investigates P&T systems operating at U.S. Air Force (USAF) installations having groundwater contaminated with Trichloroethylene (TCE). As part of this study, it was found that in 1997 the USAF was operating eighty-six P&T systems at forty-nine of its installations. The operation of many of these cleanup systems is expected to continue for an additional 20-40 years.

The Environmental Protection Agency (EPA) regulated TCE in drinking water in 1987 at a level of 5 parts per billion (ppb). Studies of groups of humans exposed to TCE have consistently indicated no overall increase in cancer risk, although small uncertain increases in certain types of cancer have been observed. This study is a compilation of information on Air Force installation pump and treat systems to submit to the EPA's Office of Drinking Water in support of a review and possible revision of the TCE Drinking Water Standard to a scientifically defensible level. Physiologically based pharmacokinetic models support a safe level of TCE in drinking water up to 2 orders of magnitude higher than the current policy based standard, or somewhere between 50 ppb and 200 ppb (Bogen, 1997). At a minimum, cleanup standards addressing drinking water aquifers should be considerably relaxed for non-potable water aquifers.

This study involved several steps. First, an inventory of all the USAF P&T systems was performed (Appendix A). This involved contacting and gathering information from 101 AF installations located in the 50 U.S. states and Guam. The search revealed that the Air Force has 86 P&T systems, 61 of which have TCE as a contaminant of concern. More detailed information was gathered on thirty-one of the TCE sites. From this information statistical forecasting was

performed on 15 sites to estimate when P&T systems could be turned off based on the different remediation goals of 5 ppb, 50 ppb, and 100 ppb. Data from only 4 of the 15 sites was useable in the statistical forecasting model used for this study. Analytical data collected over time from eight of the sites, or 53%, showed increasing or very erratic concentration trends. This finding further illustrates the inefficiency of pump and treat systems in remediating TCE contaminated aquifers. Data from only 4, or 27%, of the systems studied showed a consistent downward contamination trend and were progressing toward cleanup. The remaining 3 sites had too little data to undergo statistical forecasting.

The fundamental purpose of remediating contaminated sites is to reduce risks to human health and the environment. However, reducing a small amount of risk can come at a high cost. Automobile side door protection standards save lives at $1.3 million each. OSHA asbestos regulations save one life at $89.3 million. EPA asbestos regulations save lives at $104.2 million each. The proposed OSHA formaldehyde standard cost $72 billion per life saved (Morrall, 1986). At the four sites studied, the cost to eliminate one lifetime excess cancer risk as the cleanup levels are reduced ranged from $9K to $2.4 M. The cost for each ppb reduction in TCE concentration for the four sites ranged from $5K to $1.4M. Considering just the 4 sites for which the statistical forecasting model was used, the cost savings realized from raising the TCE Drinking Water Standard or Maximum Contaminant Level (MCL) from 5 to 50 ppb would be approximately $60 million and from 5 to 100 ppb would be approximately $72 million. If the average cost savings from these 4 sites was applied to the 61 USAF TCE sites, $0.9 billion and $1.1 billion could be saved by raising the TCE MCL to 50 ppb or 100 ppb respectively.

INTRODUCTION

Over the past quarter century, the United States has placed a high priority on cleaning up sites where contaminants have leaked, spilled, or been disposed of in the soil and groundwater. Anywhere from 300,000 to 400,000 contaminated sites are scheduled for cleanup in the coming decades, at an estimated total cost as high as $500 billion to $1 trillion (National Research Council, 1994; Russell et al., 1991). The Office of Management and Budget estimates the costs of remediation at contaminated sites on property owned by the Departments of Defense, Energy,

Interior, and Agriculture and the National Aeronautics and Space Administration will total between $234 and $389 billion over the next 75 years (Federal Facilities Policy Group, 1995).

The Environmental Protection Agency (EPA) estimates the following numbers of US government sites need some type of cleanup (HTIS, 1998):

- Department of Defense (21,400): fuels, solvents, industrial waste, unexploded ordnance;
- Department of Energy (10,000): radioactive and hazardous wastes, mixed waste, and fossil fuel;
- Department of the Interior (26,000): mining and other municipal and industrial wastes;
- Department of Agriculture (3,000): hazardous and mining wastes, other chemical wastes;
- National Aeronautical and Space Administration (730): fuels, solvents, industrial wastes.

Contaminants at many of these sites have migrated into the groundwater where P&T remediation systems are in place or will be in the future. Many are questioning the ability of conventional technologies such as P&T to remediate contaminated aquifers. Pump and treat systems are one of the most widely used groundwater cleanup technologies. These systems extract contaminated groundwater and convey it to the surface where it is treated to remove the unwanted contaminants. They can be used to cleanup groundwater or to contain a plume, thereby preventing spread of contamination. The systems came into wide use in the mid-1980s; however, by the early 1990s regulators and scientists began questioning their effectiveness (DoD IG, 1997).

A 1994 National Research Council (NRC) study of conventional groundwater cleanup systems at 77 contaminated sites determined that groundwater cleanup goals had been achieved at only 8 of the sites and that full achievement of cleanup goals was highly unlikely with the in-place technologies at 34 of the 77 sites (NRC, 1994; MacDonald and Kavanaugh, 1994, 1995). The lack of commercially available technologies that can restore contaminated groundwater at reasonable cost has led to increasing pressure to limit waste cleanups to sites that pose immediate risks to human health rather than applying costly and potentially ineffective conventional cleanup systems. The American Society of Testing and Materials (ASTM) in 1995 issued a standard entitled "Standard Guide for Risk-Based Corrective Action Applied at Petroleum

Release Sites" (known as RBCA) that outlines a procedure for limiting the cleanup of underground storage tanks sites to those posing immediate risks (ASTM, 1995). RBCA is a process for determining site-specific risk factors and setting site-specific cleanup goals. If RBCA were widely applied at all types of contaminated sites, a large percentage of sites currently marked for remediation would not be actively cleaned up (Begley, 1996) and many systems currently operating would be turned off much sooner.

This study is primarily concerned with P&T systems operating at U.S. Air Force (USAF) installations having Trichloroethylene (TCE) contaminated groundwater. As part of this study, it was found the USAF is operating eighty-six P&T systems at forty-nine of its installations. Trichloroethylene is the predominant contaminant of concern; it is present at sixty-one, or 71%, of the P&T systems and more will be operating in the future. The operation of many of these cleanup systems is expected to continue for an additional 20-40 years. The restoration of these sites has the potential to cost the USAF, and thus the taxpayers, several billion dollars over the next decade. Clearly, the time is right for a reevaluation of these systems and their cleanup goals.

Background

TCE was used widely by the USAF as a metal degreaser and solvent for over 40 years. It is especially valuable because of its cleaning properties, low flammability, and lack of a measurable flashpoint. TCE is a colorless, volatile liquid, and an unsaturated aliphatic hydrocarbon. In 1995, U.S. demand for TCE was about 128 million pounds (Halogenated Solvents Industry Alliance, Inc., 1996).

The Environmental Protection Agency (EPA) regulated TCE in drinking water in 1987 at a level of 5 parts per billion (ppb) (ATSDR, 1997). At that time TCE was considered a probable human carcinogen based on the results of animal bioassays. Using the animal bioassay data, a concentration of 3.1 ppb was established to equal an excess cancer risk of 1 in one million (1E-6). This translates to an excess cancer risk of 1.6 in one million in the case of the 5 ppb MCL established for TCE using the assumption that a 70 kg man consumes 2 liters of water a day, 350 days a year, for a residence time of 30 years. In establishing a drinking water MCL, EPA

established a non-enforceable health goal of zero and set the enforceable MCL at 5 ppb based on technological feasibility. One ppb is equivalent to one drop in 17,000 gallons.

Studies of groups of humans exposed to TCE have consistently indicated no significant overall increase in cancer risk, although small uncertain increases in specific types of cancer have been observed. A retrospective study of 7,000 U.S. aircraft maintenance workers, followed for an average of 25 years, failed to demonstrate any significant association between exposure to TCE and an excess rate of cancer. A similar study of 2,600 exposed workers found no increase in cancer mortality despite additional exposure through contaminated groundwater (Halogenated Solvents Industry Alliance, Inc., 1996). The International Agency for Research on Cancer (IARC) has reviewed TCE four times. In the first 3 reviews IARC concluded that TCE could not be classified with regard to its possible carcinogenicity in humans. However, in 1995, IARC considered the epidemiological evidence as suggestive of a cancer hazard to humans and reclassified TCE as 2A (possibly carcinogenic to humans) (International Agency for Research on Cancer, 1995). Health and Welfare Canada proposed (and finalized) a Maximum Acceptable Concentration for TCE in drinking water of 50 ppb which is ten times the MCL in the U.S.

Conventional technologies for cleaning contaminated groundwater are based on the principle that if enough water is pumped from the site, the contaminants will eventually be flushed out. A pump and treat system extracts contaminated groundwater then conveys it to the surface where it is treated to remove the unwanted contaminants. As mentioned earlier, TCE is the predominant contaminant of concern for sixty-one USAF P&T remediation systems. Each of these systems have, on average, an additional 22 years of operation (Karta Technology, Inc., 1997).

Limitations of P&T Systems in Remediating TCE Contaminated Aquifers

The effectiveness of P&T systems depends directly on site conditions and contaminant chemistry. As the complexity of the contaminated site increases, the likelihood that a P&T system will attain a cleanup goal that meets drinking-water standards decreases. Particularly difficult to cleanup are the chlorinated solvents such as TCE (DoD IG, 1997). Because of their widespread use in many applications, TCE and other chlorinated solvents are among the most common groundwater contaminants. Nine of the 20 most common chemicals found in

groundwater at Superfund sites are chlorinated solvents. TCE is the contaminant most commonly detected in groundwater at Superfund sites (NRC, 1994).

The movement and dispersion of TCE in the subsurface differs depending on whether the solvents were released in a dissolved or undissolved form. If released in dissolved form, TCE migration is governed largely by hydrogeologic processes. If released in undissolved form, the liquid TCE will migrate downward through the soil column under the force of gravity. A portion of the solvent will be retained in the soil pores, but if sufficient TCE is present, it will saturate the available soil space and continue moving downward until it encounters a physical barrier or the water table. When encountering the water table, it will spread out along the water table until enough mass accumulates to overcome capillary forces (Schwille, 1988). Due to the much greater density of TCE relative to water, it will penetrate the surface of the water table and travel downward by gravity until it is diminished by sorption or it encounters an aquitard (low permeability formation). If there is sufficient liquid mass, it can accumulate along the aquitard and pool in low areas and irregularities where removal ability is greatly diminished (Cohen and Mercer, 1993).

The flushing process employed by P&T systems has limited effectiveness, especially for cleaning up undissolved sources of contamination beneath the water table. Key contaminant and subsurface properties that interfere with flushing include the following (NRC, 1994; MacDonald and Kavanaugh, 1994, 1995):

> *Immiscibility of contaminants with water:* Many contaminants are extremely difficult to flush from the subsurface because of their relatively low solubility in water.
>
> *Diffusion of contaminants into micropores and zones with limited water mobility:* The microscopic pores and zones with limited water mobility into which contaminants may diffuse are extremely difficult to flush with water because of their small size and inaccessibility.
>
> *Sorption of contaminants to subsurface materials:* Flushing out contaminants that have sorbed to underground soils is a very slow process because of the slow rate of desorption.

Heterogeneity of the subsurface: Prediction models for determining the routes of travel of contaminants and of water used to flush out contaminants are not always accurate because of the heterogeneous nature of the subsurface.

Putting Risks in Perspective

The fundamental purpose of remediation technology is to reduce risks to human health and the environment. Determining the amount of risk present at a site can be very difficult because quantitative estimates of health and environmental risks at contaminated sites are highly uncertain (NRC, 1997). Other factors complicate efforts to determine the health effects of exposure to contaminated groundwater and the effects of reducing this exposure. Detecting health effects for which there is a long interval between exposure and the onset of sickness may be difficult. Also, the control group (group of people not living near the contaminated site) may also have been exposed to contaminants from some other source, such as the work place. Factors such as smoking, poor diet, and absence of prenatal and preventive health care may bias the results of health investigations (NRC, 1994). The result of these uncertainties is that opinions about the risks posed by site contamination can vary depending on who conducted the investigation and who interprets the results.

Health and safety risks comprise one aspect of our lives that we would all like to eliminate. Unfortunately our economic resources limit us in our ability to do so. If the entire American Gross National Product were devoted to preventing fatal accidents, we would be able to spend an average of only $55 million per fatality (Viscusi, 1993). Other demands on these limited resources such as food, housing, and recreation, would further limit the amount which could be spent on risk reduction.

The US government has many opportunities to reduce the risks faced by its citizens. Airplane cabin fire protection costs $200,000 per life saved. Automobile side door protection standards save lives at $1.3 million each. OSHA asbestos regulations save a life at $89.3 million while EPA asbestos regulations save lives at $104.2 million each. A proposed OSHA formaldehyde standard would cost $72 billion per life saved (Morrall, 1986). Which of these regulations are cost effective and which are over priced for the amount of risk that is alleviated? Cancer is an

endpoint of great concern to people. Table 1 shows cancer risks from environmental agents (US EPA, 1991).

TABLE 1. CANCER AGENTS AND LIFETIME RISK

Cancer Causing Agents or Situations	Approximate Lifetime Risk of Cancer
Exposure to the sun	1 in 3
Cigarette smoking (pack or more per day)	1 in 100
Natural radon in home indoor air	8 in 100
Outside radiation (radon and cosmic rays)	1 in 1,000
Persons in room with smoker	7 in 10,000
Man-made chemicals in home indoor air	2 in 10,000
Outdoor air in industrialized areas	1 in 10,000
Human-made chemicals in most foods	1 in 100,000 or less
Chemical exposure at most uncontrolled hazardous waste sites	1 in 10,000 to 1 in 1,000,000

Studies show that people are less concerned about natural risks, such as radon, than they are about unfamiliar risks, such as living near an uncontrolled hazardous waste site. Most hazardous waste sites pose cancer risks ranging from 1 in 10,000 to 1 in a 1,000,000 before cleanup; or 100 to 10,000 times less than the cancer risks posed by radon in homes. But people are far more concerned about contracting cancer from hazardous waste sites, even if cancer risks are as small as 1 in a 1,000,000. The hazardous waste site is man-made, less understood, and is therefore perceived to be more threatening than radon in homes. However, radon in homes presents far greater danger than most hazardous waste sites (US EPA, 1991).

Each of us has different levels of risk that we find acceptable. There is no universally acceptable level. There are also levels of risk which we have very little control over. In the U.S., men have a 1 in 2 lifetime risk of developing cancer. For women the risk is 1 in 3 (American Cancer Society). Of course practicing a healthy lifestyle can somewhat reduce an individual's odds of contracting cancer. Sixteen individuals in a population of 10 million, may experience an increased risk of contracting cancer through ingestion of 5 ppb TCE in their drinking water over a lifetime. This equates to an excess cancer risk of 0.0000016. Theoretically, the probablity (0.5) of contracting cancer by American males is increased to only 0.5000016 by exposure to 5 ppb TCE in drinking water. The lifetime risk of death by motor vehicle accident in the U.S. is 1 in 65 people; death by an accident in the home is 1 out of 130 people, and 1 out of 12 smokers will die

from lung cancer. When placed in perspective, the lifetime cancer risks encountered by exposure to 5 ppb TCE in drinking water is negligible but is costing the US billions of dollars. It should also be noted that very few of the TCE contaminated aquifers could be classified as drinking water aquifers. Primarily, aquifers contaminated with TCE are shallow and have always been unsuitable as a drinking water resource due to low productivity or other characteristics that would require excessive water treatment. In retrospect, when conducting the survey, we should have questioned how many of the contaminated aquifers were, or had been, used as a drinking water resource. Those aquifers which have never been, and will never be, used as a drinking water resource should not be required to undergo rigorous and expensive remediation processes unless they may possibly spread the contamination to other resources or become an exposure pathway.

METHODOLOGY

Inventory of USAF P&T Systems

The first task for this project was an inventory of all USAF P&T systems (Appendix A). This involved contacting 101 AF installations and gathering the following information: site identification number, contaminants and their cleanup goal, type of P&T, date system became operational, size of plume, whether the system is achieving or progressing toward cleanup goals, and estimated date to achieve cleanup. This search revealed the Air Force has 86 P&T systems, 61 of which have TCE as a contaminant of concern.

More detailed information was gathered on thirty-one of these sites (Appendix B) which have TCE as the major contaminant and had been operating for a minimum of 1.5 years. From this information, analytical data from 15 sites was run through a statistical forecasting model to estimate when P&T systems could be turned off based on proposed remediation goals of 5 ppb, 50 ppb, and 100 ppb. The statistical program was developed by John Rogers, Senior Statistician at Westat. This program is based on a Microsoft Excel workbook using regression analysis to predict future contaminant trends. The analysis is performed using the history of analytical results obtained from sampling rounds. The remaining 16 of the 31 sites had characteristics which made them unsuitable for contaminant concentration forecasting in this study. Primary reasons were lack of analytical data, complex hydrogeology, lack of containment, and no

appreciable remediation progress. The statistical forecasting model was able to predict cleanup dates for only 4 of the 15 sites. Only these 4 sites showed a consistent downward contaminant concentration trend and were progressing toward cleanup. A statistical model was used in lieu of a groundwater model to forecast contaminant levels since the extensive hydrogeological data needed for the sites in most cases did not exist.

Forecasting Contaminant Concentrations

The statistical program used to derive estimates of cleanup periods produces a graph of the TCE concentrations for that well or system influent over time after analytical data gathered from the site is incorporated into it. It assigns an exponential trendline to the data points as well as a 95% Upper Confidence Interval (UCI). The trendline is basically an average of the sampling concentrations. The UCI forms an upper bound under which all sampling concentrations fall. It is assumed the aquifer TCE concentration will reach the various cleanup levels at some year between that designated by the trendline and UCI. However, the 95% UCI level is used to predict a conservative time point when that well or system influent will reach the cleanup levels of 100 ppb, 50 ppb, and 5 ppb TCE.

When using individual well data, once the prediction of future operating time to achieve a cleanup level has been made for each well at a site, the median of the cleanup dates for the wells is found and this is designated as the predicted date in which that site P&T system can be shut down based on a particular cleanup level. If using system influent concentration data, the data is fed into the model and the resulting graph predicts the various cleanup intervals. Graphs of the concentrations and their trendlines over time at various sites can be seen in Appendix C.

Forecasting Lifetime Excess Cancer Risks

The forecasting of lifetime excess cancer risk at the 4 sites was accomplished by using the statistical model algorithm. The model developed risk curves based on the years when the monitoring wells or system sampling point reached each of the 3 contamination levels. The risk curves are plotted against the P&T system cumulative costs. This was done to illustrate that the costs to operate a P&T system increases greatly over time to alleviate a very small amount of risk.

The risk is based on the assumption that lifetime excess cancer risk through exposure to increasing concentrations of TCE progresses in a linear fashion. We assumed the lifetime excess cancer risk through the ingestion of 5 ppb TCE in drinking water is 1.6 in one million; exposure to 50 ppb would be 16 in one million and at 100 ppb the risk would be 32 in one million. Risk curves were developed based on the dates the aquifer would reach these 3 levels of contamination. The risk curves were generated by using the same algorithms used in the contaminant forecasting model to graph the trendline and 95% UCI contaminant concentration curves. The model was first used to forecast contaminant concentrations and then risk was derived based on the forecasted year the aquifer would reach those concentrations. The trendline is an average of the sampling concentrations and is used as a representation of the average risk. The 95% UCI forms an upper bound under which, almost certainly, all sampling concentrations would fall and would conservatively represent an upper boundary of potential risk. This allows for a range of risk. It is assumed that the actual risk falls somewhere between these two boundaries. Figures 3, 6, 9, and 12 show the changes in average lifetime cancer risk superimposed on the cumulative costs for the 4 sites amenable to concentration forecasting.

Assessing the Costs

For this study only direct system costs were considered. Costs that can be attributed to a P&T system are the Remedial Investigation and Feasibility Study (RI/FS), design, installation, operations and maintenance, components, monitoring for system performance, and long term monitoring after achieving the remediation goal. For the purpose of this study it is assumed that RI/FS, long term monitoring, and design costs would be the same whether the cleanup goals were 5, 10, or 100 ppb. Therefore, baseline costs only consider system installation, operations and maintenance, major component replacement and repairs, and monitoring for system performance. The costs provided by the installations were given as 1996 costs except for installation costs that reflect the year the system was installed. All costs were converted to constant year 1996 dollars and then spread over the years of operation using the Office of the Secretary of Defense inflation index issued 14 January 1998.

Cumulative costs and price to capture each gallon of TCE through time was also determined based on system construction and modification costs, operation and maintenance, monitoring, and system replacement costs. Costs were extrapolated from 1996 costs to other years of operation. Installation costs, Operation and Maintenance (O&M), monitoring, and major component replacement costs were primarily obtained from the Department of Defense Office of the Inspector General's project, "Evaluation of DoD Waste Site Groundwater Pump-and-Treat Operations." Installation costs were converted to constant FY 1996 dollars and then spread over the years of expected operation by using the Office of the Secretary of Defense inflation rate for non-personnel issued by SAF/FMC, 14 January 1998. Graphic comparisons (Figures 1-12) were then made between cumulative costs versus excess cancer risk, amounts of TCE captured, and yearly average TCE captured.

A cost effectiveness analysis was also performed on the four sites as a way of comparing the amount of TCE concentration and risk reduced to the amount of remediation dollars spent to attain the various cleanup levels. Cost effectiveness analysis is a way of determining the return on investment. Applying the amount of dollars spent installing and operating a P&T system against the improvement in environmental quality or its affect on lifetime excess cancer risks, can reveal a cost effectiveness ratio (JAMA, 1996). Cost effectiveness ratios for the four sites are depicted in Table 5 located in the Cost Effectiveness Analysis section.

Most of the system costs gathered for the 31 TCE sites in Appendix B were derived from the DoD Office of the Inspector General's survey of P&T systems. Where component replacement costs were not provided they were estimated as being 75% of the system construction and modification costs. Where TCE price per gallon figures were not provided they were estimated based on system operation, maintenance, monitoring, and amortized system construction and modification costs. Where other contaminants are present, costs for TCE and its breakdown products were estimated as a portion of the costs. If the installation could not provide us with the amount of TCE captured it was estimated using system influent concentrations and pumping rates. For the 4 sites for which contaminant forecasting was performed, Figures 1, 4, 7, and 10 display graphs of Cumulative Gallons of TCE versus Cumulative Costs, and figures 2, 5, 8, and 11 display graphs of Yearly TCE Captured versus Cumulative Costs.

RESULTS

Results of Data Gathering

An inventory of all the USAF P&T systems (Appendix A) was performed by contacting 101 Air Force installations. The following information was disclosed:

- The USAF is operating eighty-six P&T systems at forty-nine installations.
- Trichloroethylene is the predominant contaminant of concern; it is present at sixty-one, or 71%, of the P&T systems.
- The study also revealed that forty-three, or 50%, of the systems are achieving containment of the contaminant plume per the site POC we spoke with.
- Fifty, or 58%, are progressing towards established cleanup goals.
- Sixty of the systems have an estimated date when they will achieve cleanup and can cease operation in 1 to 47 years. The average is 22 additional years of operation.
- The known contaminant plume sizes ranged from 0.03 to 1,470 acres. The average is 134 acres.

More detailed information was gathered for thirty-one sites from the inventory which have TCE as the major contaminant and have been in operation at least 1.5 years (Appendix B). The following information was disclosed:

- In constant FY96 dollars, $168.5 million was spent to install the 31 treatment systems for an average of $8 million each.
- Operations, maintenance, and monitoring costs for the 31 systems totaled $19 million in 1996 alone.
- The combined operating period for the 31 systems for which influent data was gathered totaled 101 years and roughly 35,000 gallons of TCE was captured during this time.
- This averages out to 347 gallons recovered per year from the 31 systems or 11 gallons per P&T system per year.
- Cost per gallon of TCE recovered varied from a low of $6 at Kelly AFB to a high of almost $2 million per gallon at Otis ANG.
- Average cost of TCE recovered from the 31 systems is $206,000 per gallon.

Forecast of Contaminant Concentrations

Analytical data from the following 15 P&T sites was examined for use in the statistical forecasting model: OT-12, Plant 44; WP-07, Hill AFB; LF-05, McChord AFB; SD-19, Myrtle Beach AFB; LF-05, Wright Patterson AFB; OT-24 and SS-17/21/47, Wurtsmith AFB; FSA-1, Plant 4; LF-1 and LF-3, Arnold AFB; LF-02, Fairchild AFB; GC-070, George AFB; OT-01, Tinker AFB; SS-016, Travis AFB; and DP-02, KI Sawyer AFB. These sites were chosen based

on the following criteria: TCE was the primary contaminant of concern; the site had a fairly consistent alluvial geology, the P&T system was servicing a single aquifer and had been in operation at least 2.5 years.

Data from only 4 of the 15 sites was useable in the model. Analytical data collected over time from eight of the sites, or 53%, showed increasing or very erratic concentration trends. This finding further illustrates the inefficiency of pump and treat systems in remediating TCE contaminated aquifers. Only 4 of the 15 systems studied showed a consistent downward contamination trend and were progressing toward cleanup. The remaining 3 sites had too little data to undergo statistical forecasting. The statistical forecasting model performs best on those sites which have been consistently sampled over a number of years and show a downward contaminant concentration trend. The following sites fit these qualifications: OT-12 at Plant 44, LF-05 at Wright Patterson AFB, OT-24 and SS-17/21/47 at Wurtsmith AFB.

OT-12, PLANT 44

This system has been in operation since 1987 and has an extensive monitoring and extraction well network. The site has one of the largest estimated plume sizes of 440 acres and, of all the systems studied, has the highest system influent flow rate of 3,800 gallons per minute (GPM). Contaminant forecasting was performed on nine monitoring wells located in the central plume area. Table 2 lists the nine monitoring wells and the forecasted years when each is predicted to reach 100 ppb, 50 ppb, and 5 ppb. The concentration forecasting graphs for these wells can be seen in Appendix C. To determine when the *aquifer* TCE concentration would reach the three target cleanup levels, the median year that each individual well reached the target cleaning level was calculated. Using this method it was determined the aquifer TCE concentration would drop to 100 ppb in the year 2002. If the TCE MCL was raised to 50 ppb the system could be stopped in 2007 and the current TCE MCL of 5 ppb would be reached in 2026. By raising the MCLs to 50 ppb or 100 ppb, 19 to 24 years of operating expenses could be saved respectively.

LF-05, WRIGHT PATTERSON AFB

The P&T system at LF-05 has been operating since 1992. System flow rate is 700 GPM and groundwater treatment is accomplished in air sparging tanks. Plume size is roughly 4 acres.

TCE analytical data from five monitoring wells was analyzed and contaminant concentrations were forecasted. Four of the wells had a consistent downward concentration trend through time, however well MW-132 showed a slightly increasing trend. The concentration graphs can be seen in Appendix C. MW-132 is the most downgradient well and its possible that groundwater having a high TCE concentration may have been downgradient of the extraction system at installation, was not captured, and is now moving through the area in the vicinity of MW-132. It is also possible this well is situated in an area having somewhat higher transmissivity rates than at the other well locations and this may be responsible for the slightly increasing concentration trend. Data from well MW-132 was not used as part of the forecast since a downward concentration trend is required.

TABLE 2. FORECAST OF INDIVIDUAL WELL CLEANUP DATES WITH DIFFERENT MCLS, OT-12, PLANT 44

Well	**100 ppb**	**50 ppb**	**5 ppb**
M-23	2003	2007	2021
M-25	1994	1997	2004
M-2B	2002	2007	2026
M-3A	2000	2004	2020
M-5	2014	2019	2038
M-7	2002	2005	2018
M-8	2007	2030	2127
M-9	1997	2010	2102
M-41	2011	2016	2035
Median	**2002**	**2007**	**2026**

Table 3 lists the four monitoring wells and the forecasted years when each is predicted to reach 100 ppb, 50 ppb, and 5 ppb. The concentration forecasting graphs for these wells can be seen in Appendix C. To determine when the aquifer TCE concentration would reach the three target cleanup levels, the median year that each of the 4 individual well reached the target cleanup level was calculated. Using this method it was determined the aquifer TCE concentration would drop

to 100 ppb in 1998 and to 50 ppb in the year 2000. It will reach the current TCE MCL of 5 ppb in the year 2006. By raising the MCL to 50 ppb or 100 ppb, 6 to 8 years of operating expenses could be saved respectively.

TABLE 3. FORECAST OF INDIVIDUAL WELL CLEANUP DATES WITH DIFFERENT MCLS, LF-05, WRIGHT PATTERSON AFB

Well	100 ppb	50 ppb	5 ppb
HD-11	1998	2000	2005
131-M	1998	2000	2006
CW5-85	2002	2005	2017
CW5-55	1996	1998	2003
Median	**1998**	**2000**	**2006**

OT-24, WURTSMITH AFB

The P&T at OT-24, also known as Mission Drive, has been operating since May 1988. Remediation is accomplished through air stripping and system flow rate is 180 GPM. Plume size is roughly 109 acres.

Monitoring wells at this site are not sampled on a scheduled basis. However the treatment system influent is sampled weekly and is the primary means of monitoring this site. TCE sampling data from July of 1993 to May of 1997 was run through the statistical forecasting tool. Influent TCE concentrations were no more than 100 ppb in 1997 and it was determined with 95% confidence that influent TCE concentration would be no more than 50 ppb in the year 2000 and 5 ppb in the year 2007. It is understood that sampling a system's influent is not as good an indicator of aquifer conditions as the sampling of monitoring wells but it will still allow for a rough estimate of attainment periods.

SS-17/21/47, WURTSMITH AFB

This site is also known as the Arrow Street site. It has been at various stages of operation since 1981. It employs an air stripper with granular activated carbon as a backup. The plume size is roughly 48 acres and system flow rate is 590 GPM.

Monitoring of TCE concentrations at this site is accomplished primarily by sampling the P&T system influent. TCE sampling data from July of 1993 to May of 1997 was run through the statistical forecasting tool. All TCE sample concentrations were below 100 ppb and did not exceed 50 ppb in 1996. If the TCE MCL was 100 ppb this site may have not required remediation and with an MCL of 50 ppb the system may have shut down in 1996. It was determined with 95% confidence that the influent TCE concentration would decrease to 5 ppb in the year 2041. The concentration graph for this site can also be seen in Appendix C.

Assessing the Costs

OT-12, PLANT 44

The statistical forecasting model used for this study predicted the TCE concentration at this site would reach 100 ppb in 2002, 50 ppb in 2007, and 5 ppb in 2026. By the year 2026 the system is predicted to only capture 0.4 gallons TCE for that year at a cost of $306K or $764K/gallon. If the MCL was raised to 50 ppb or 100 ppb the TCE per gallon costs would be $71K and $38K respectively. Cumulative costs to operate the P&T system until 2002 would be $26M, until 2007 it would cost $37M, and $87M if operated until 2026. When the aquifer TCE concentration reaches 100 ppb, estimated to occur in 2002, 1,700 gallons of TCE will have been captured at a cost of $15,000 per gallon. By 2007 a total of 1,948 gallons of TCE will have been captured at a cost of $19,000 per gallon. By the year 2026, when its predicted the TCE concentration will reach 5 ppb, 2,186 gallons of TCE will have been captured at a cost of $40,000 per gallon. Figures 1 and 2 are graphs of Cumulative Gallons TCE Versus Cumulative Costs and Yearly Average TCE Captured Versus Cumulative Costs, respectively. Figure 3 graphs the Lifetime Excess Cancer Risk versus Cumulative Costs for this site. Table 4 (Page 29) lists the various predicted costs and risks associated with the three MCLs for this site.

LF-05, WRIGHT PATTERSON AFB

Through the use of the forecasting model, it was determined this aquifer would reach a contaminant concentration of 100 ppb in 1998, 50 ppb in 2000, and the current TCE MCL of 5 ppb in the year 2006. By raising the MCL to 50 ppb or 100 ppb, 6 to 8 years of operating

Figure 1. Cumulative Gallons TCE VS Cumulative Costs, OT-12, Plant 44

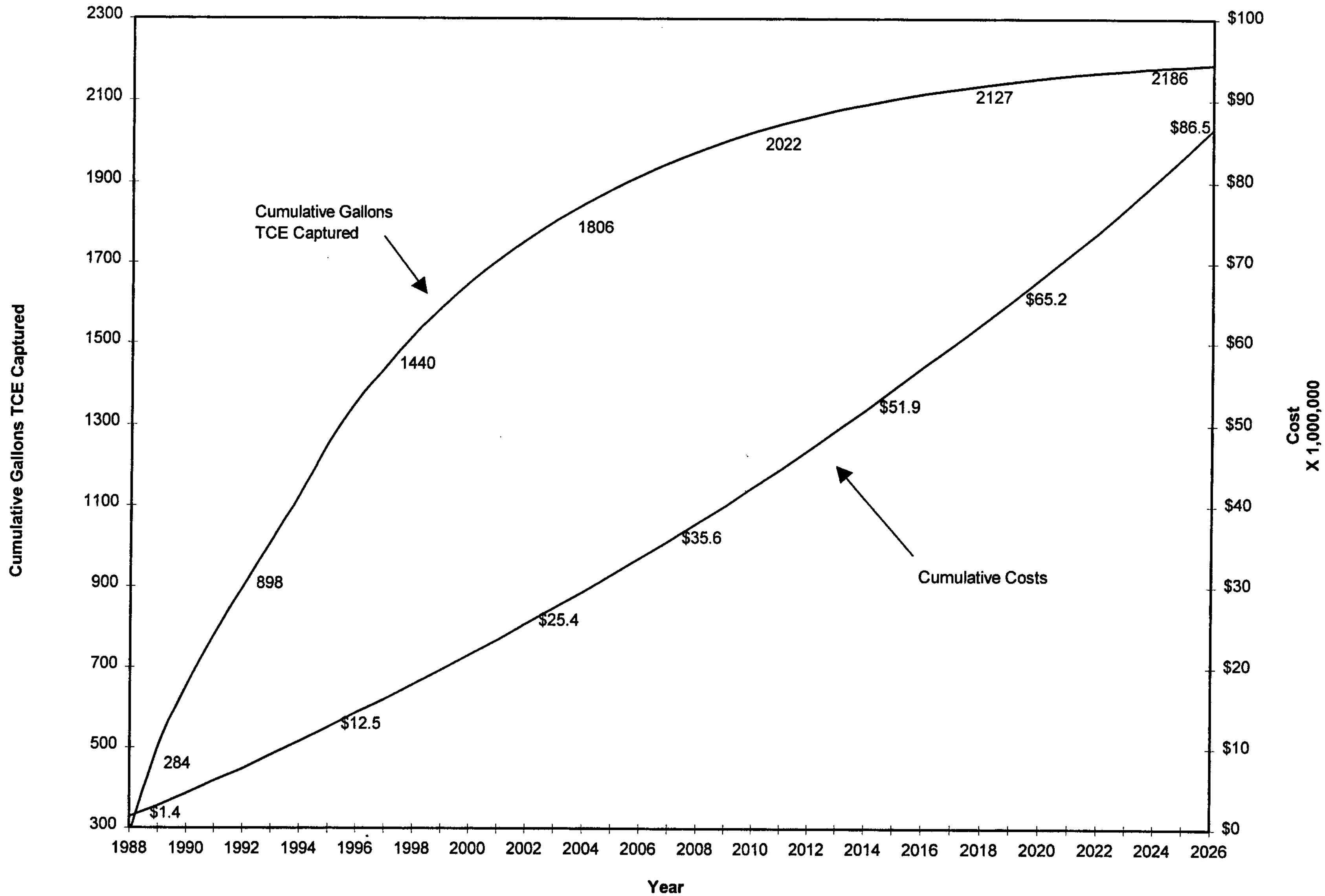


Figure 2. Yearly Average TCE Captured VS Cumulative Costs, OT-12, Plant 44

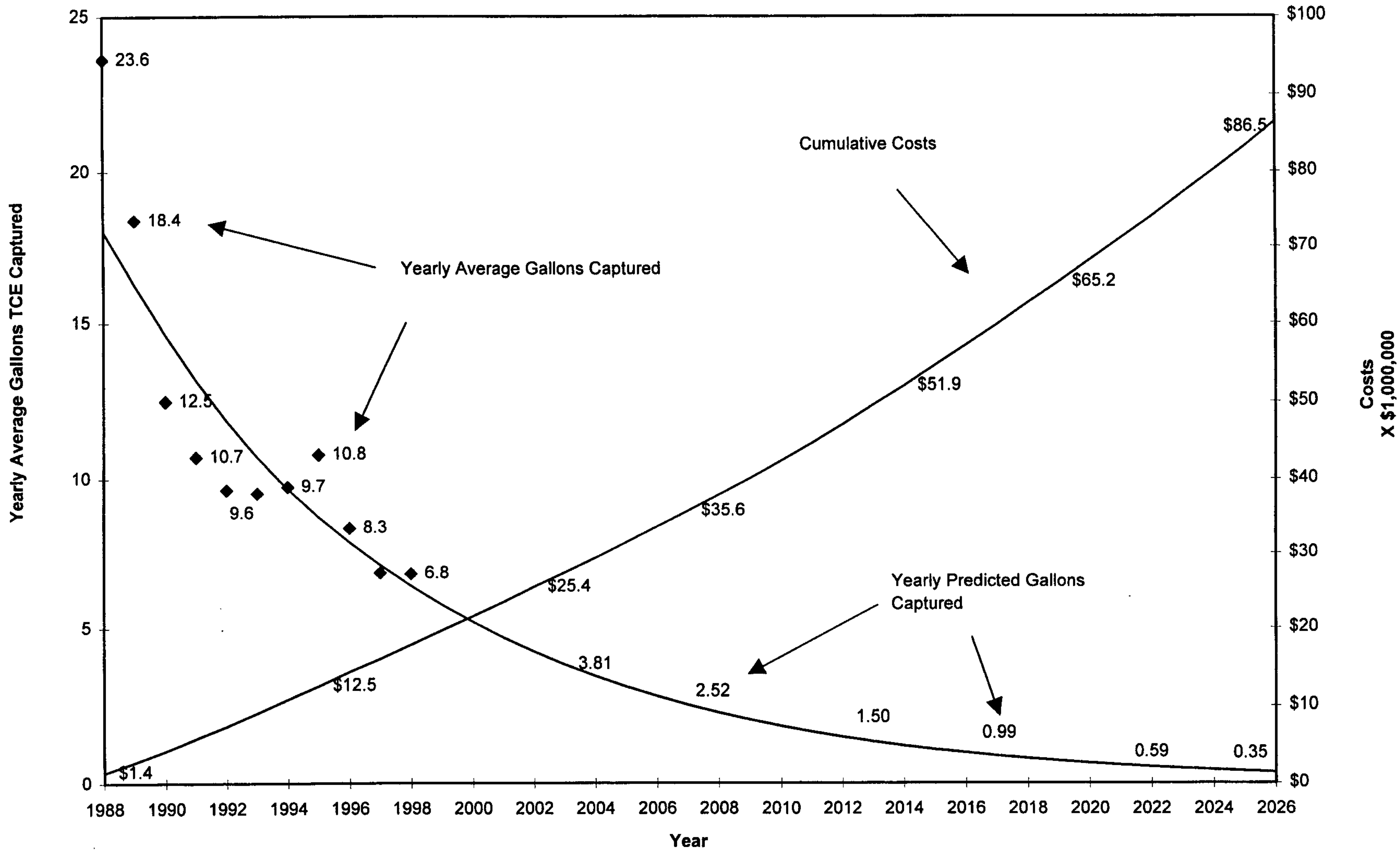
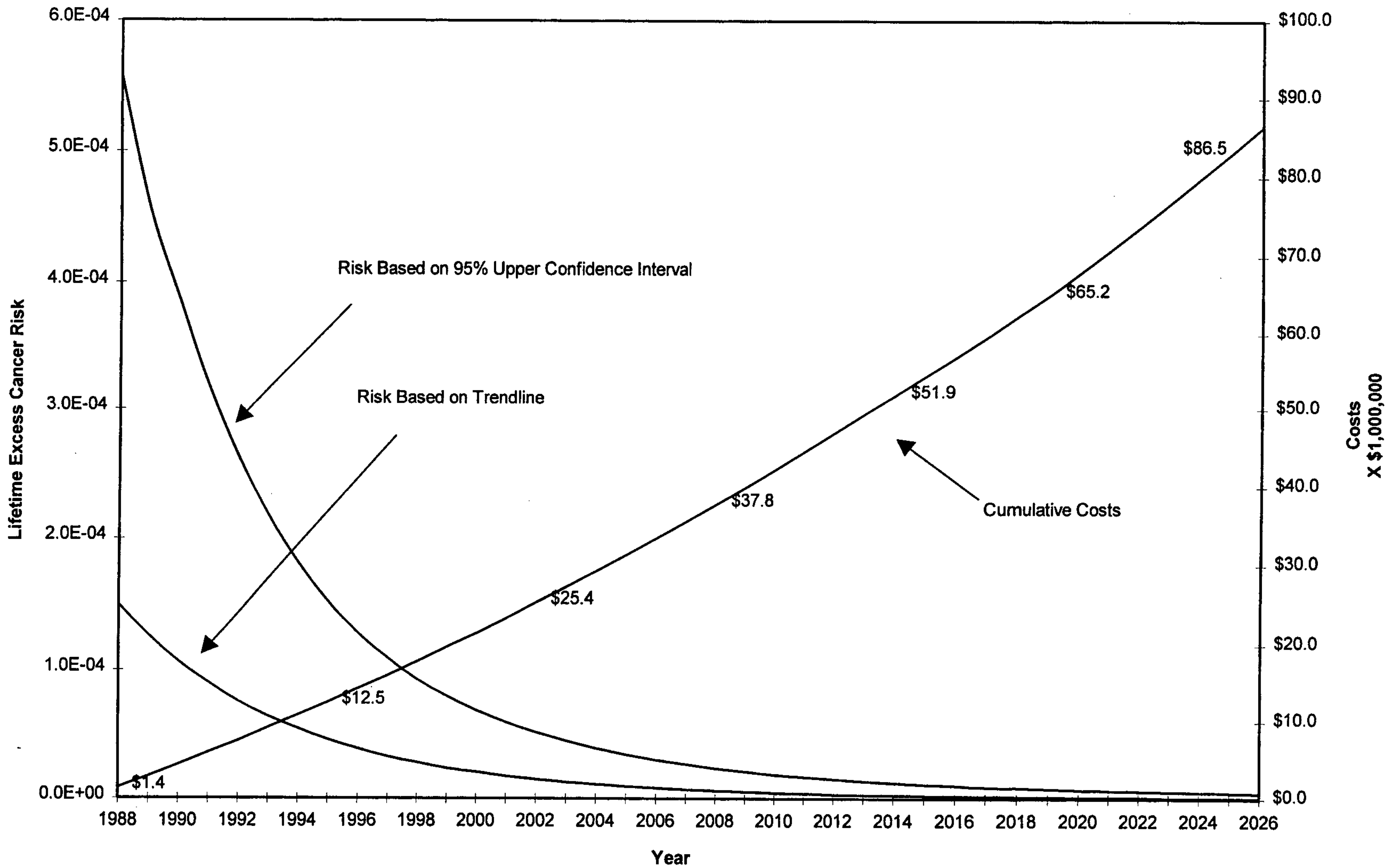


Figure 3. Lifetime Excess Cancer Risk VS Cumulative Cost, OT-12, Plant 44



expenses could be saved respectively. By the year 2006, it is anticipated that the P&T system will achieve the predicted 5 ppb cleanup level. For the year 2006, it is estimated that only 0.06 gallons of TCE will be captured for a cost of $390K or $6.5M per gallon. If the MCL was raised to 50 or 100 ppb the cost per gallon would decrease to $2.1M or $492K respectively. Cumulative costs to operate the system until 1999, 2000, or 2006 would be $2.7M, $3.5M, or $6.3M, respectively.

When the aquifer TCE concentration reaches 100 ppb, estimated to occur in 1998, 6.6 gallons of TCE will have been captured at a cost of $409K per gallon. By 2000, a total of 6.9 gallons of TCE will have been captured at a cost of $507K per gallon. By the year 2006, when its predicted the TCE concentration will reach 5 ppb, 7.3 gallons of TCE will have been captured at a cost of $863K per gallon. Table 5 (page 35) summarizes these findings. Figure 4 graphs Cumulative Gallons TCE versus Cumulative Costs for this site and Figure 5 graphs Yearly Average TCE Captured versus Cumulative Costs. Figure 6 graphs the Lifetime Excess Cancer Risk versus Cumulative Costs. Table 4 (page 29) lists the various predicted costs and risks associated with the three MCLs for this site.

<u>OT-24, WURTSMITH AFB</u>

Using the statistical model it was predicted the influent TCE concentration at OT-24 would be no more than 100 ppb in 1997, 50 ppb in the year 2000, and 5 ppb in the year 2007. When the aquifer TCE concentration reaches 100 ppb, 42.5 gallons of TCE will have been captured at a cost of $14K per gallon. By 2000, a total of 50.6 gallons of TCE will have been captured at a cost of $19K per gallon. By the year 2007, when its predicted the TCE concentration will reach 5 ppb, 52.1gallons of TCE will have been captured at a cost of $26K per gallon. In the year 2007 alone, the cost to recover a gallon of TCE would be $262K although it is predicted the P&T system will only capture 1.52 gallons between 2003 and 2007. If the MCL was raised to 50 or 100 ppb the cost per gallon would decrease to $45K or $8K respectively. Cumulative costs to operate the system until 1997 would be $593K, $956K until 2000, and $1,353K if operated until 2007.

Figure 4. Cumulative Gallons TCE VS Cumulative Costs, LF-05, WPAFB

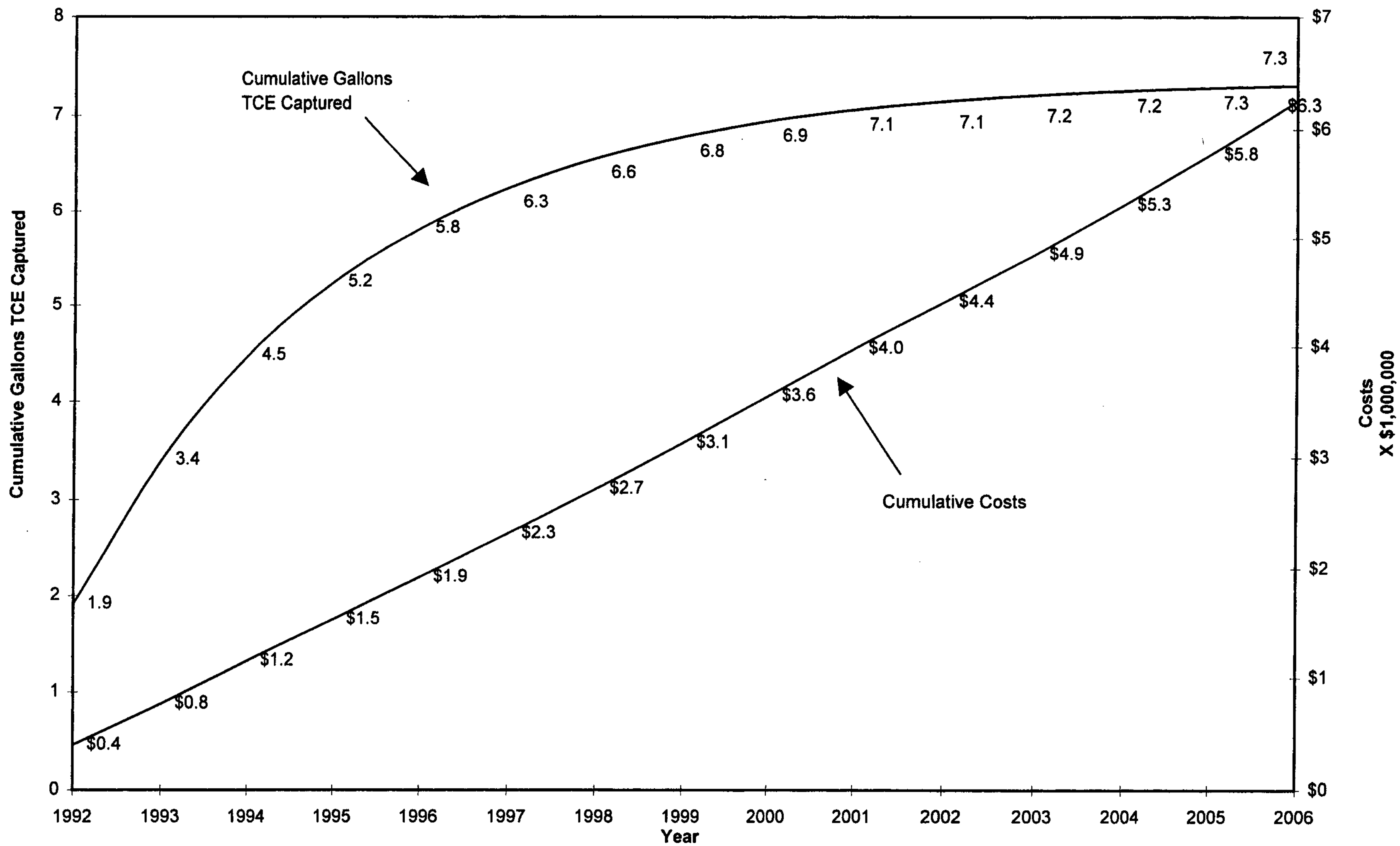


Figure 5. Yearly Average TCE Captured VS Cumulative Costs, LF-05, WPAFB

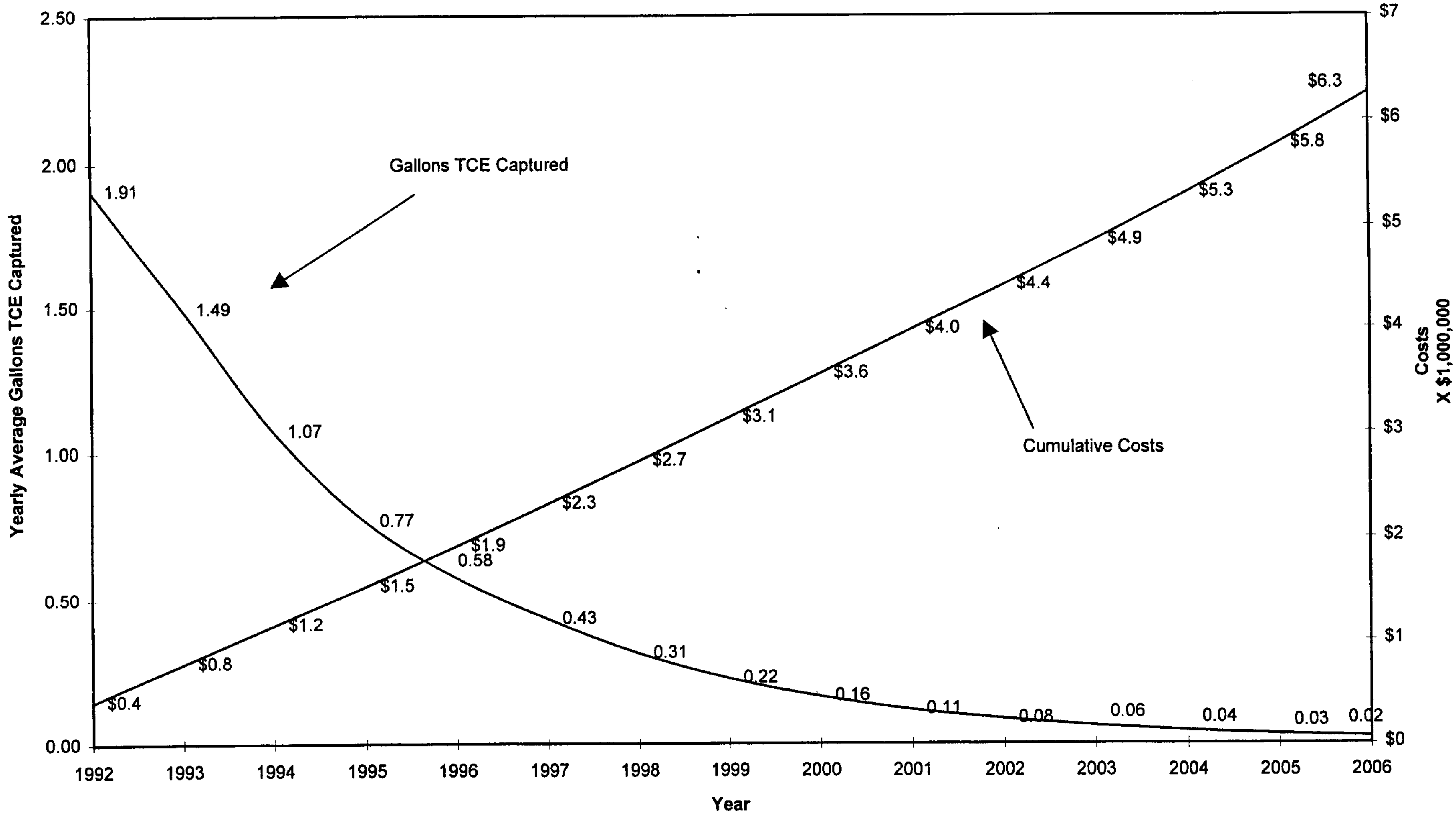


Figure 6. Lifetime Excess Cancer Risk VS Cumulative Costs, LF-05, WPAFB

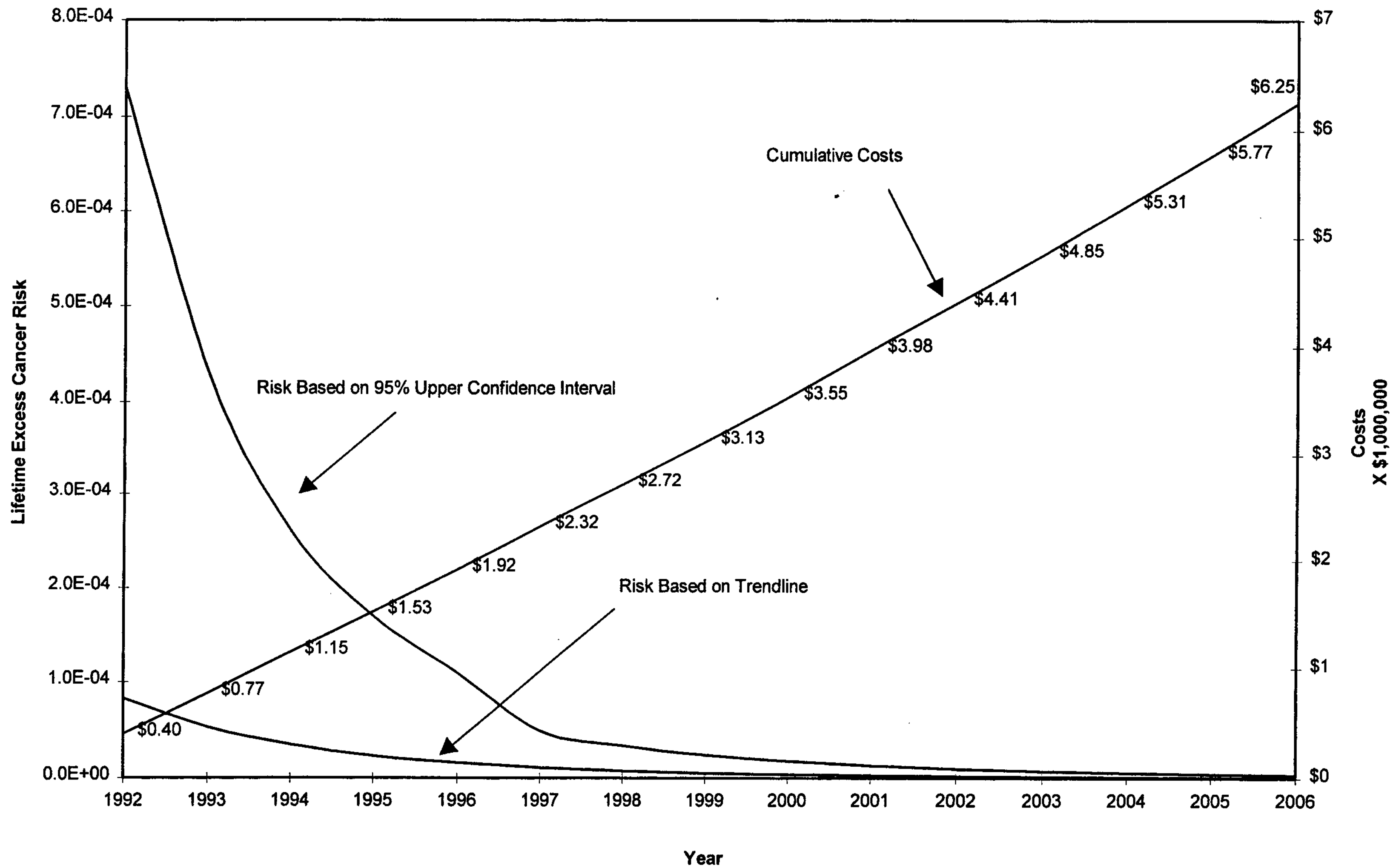


Table 4 (page 29) lists the various predicted costs and risks associated with the three MCLs for this site. Figure 7 graphs cumulative gallons TCE versus cumulative costs for this site and Figure 8 graphs gallons TCE captured versus cumulative costs. Figure 9 graphs the lifetime excess cancer risk versus cumulative costs for this site. Figures 7 and 8 are graphed in 5-year increments due to the nature of the data collection.

SS-17/21/47, WURTSMITH AFB

The predicted year for the influent concentration of this system to reach 5 ppb is 2041. The 50 ppb concentration was reached in 1996. Influent concentrations have always been below 100 ppb. In the year 2041, when the system influent concentration reaches 5 ppb, the cost to recover a gallon of TCE would be $947K. It is predicted the P&T system will only capture 1.02 gallons for the 4 years between 2038 and 2041. Cumulative costs to operate the system until 2041 would be $6.8M. If the P&T had been operated only until 1996 the cumulative costs would have been $1M for a savings of $5.8M.

When the system influent TCE concentration reached 50 ppb in 1996, roughly 31 gallons of TCE had been captured at a cost of $32K per gallon. By the year 2041, when its predicted the TCE influent concentration will reach 5 ppb, 97gallons of TCE will have been captured at a cost of $70K per gallon. Table 4 summarizes lists the various predicted costs and risks associated with the three MCLs for this site. Figure 10 graphs Cumulative Gallons TCE versus Cumulative Costs for this site and Figure 11 graphs Gallons TCE Captured versus Cumulative Costs. Figure 12 graphs the Lifetime Excess Cancer Risk versus Cumulative Costs for this site. Figures 10 - 12 are graphed in 5-year increments due to the nature of the data collection.

COST EFFECTIVENESS ANALYSIS

Cost effectiveness analysis (CEA) is a way of determining the return on investment. The cost effectiveness ratios for the four sites studied are summarized in Table 5.

Figure 7 Cumulative Gallons TCE VS Cumulative Costs, Mission St. P&T, Wurtsmith AFB

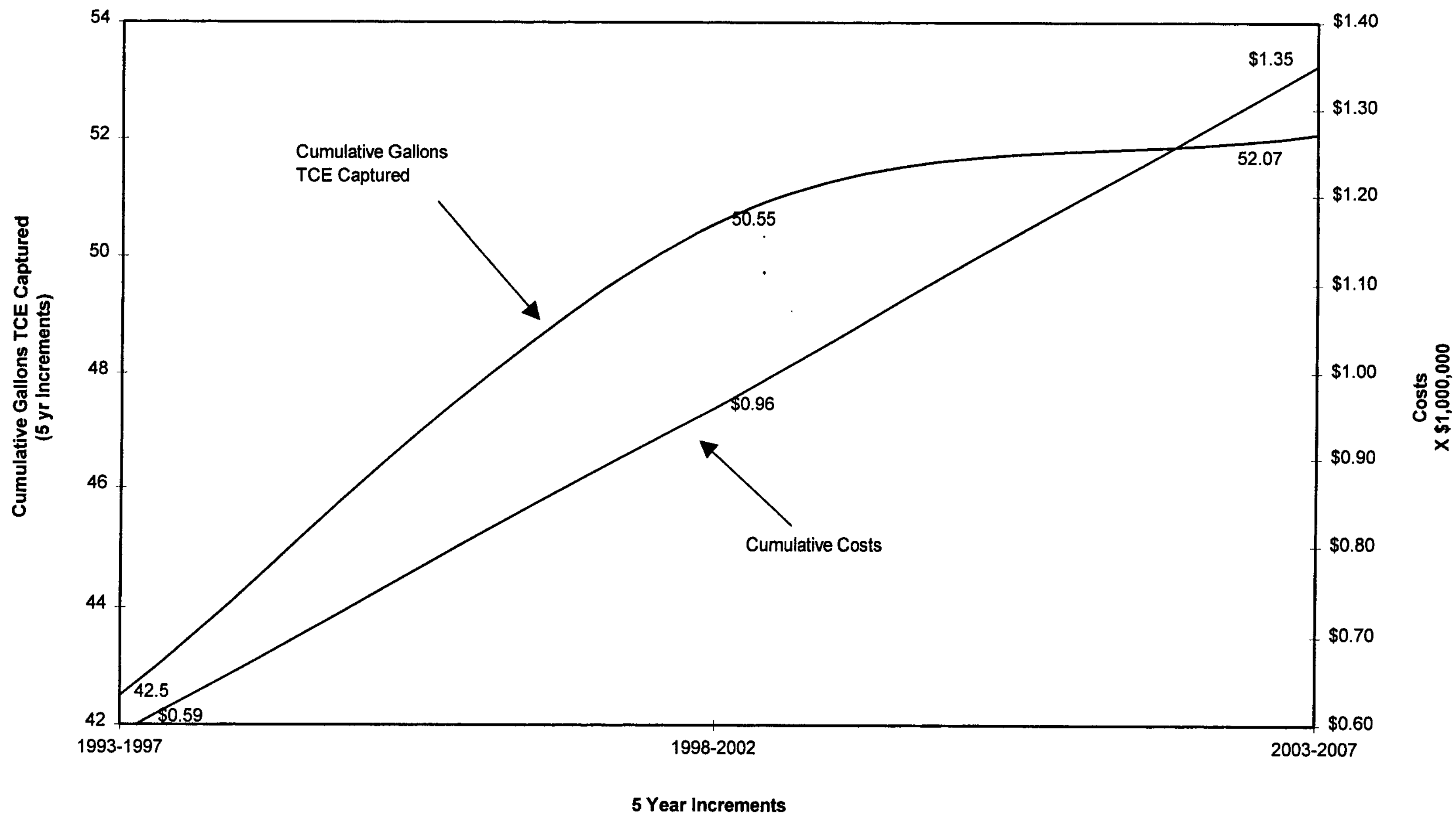


Figure 8. Gallons TCE Captured VS Cumulative Costs, Mission St. P&T, Wurtsmith AFB

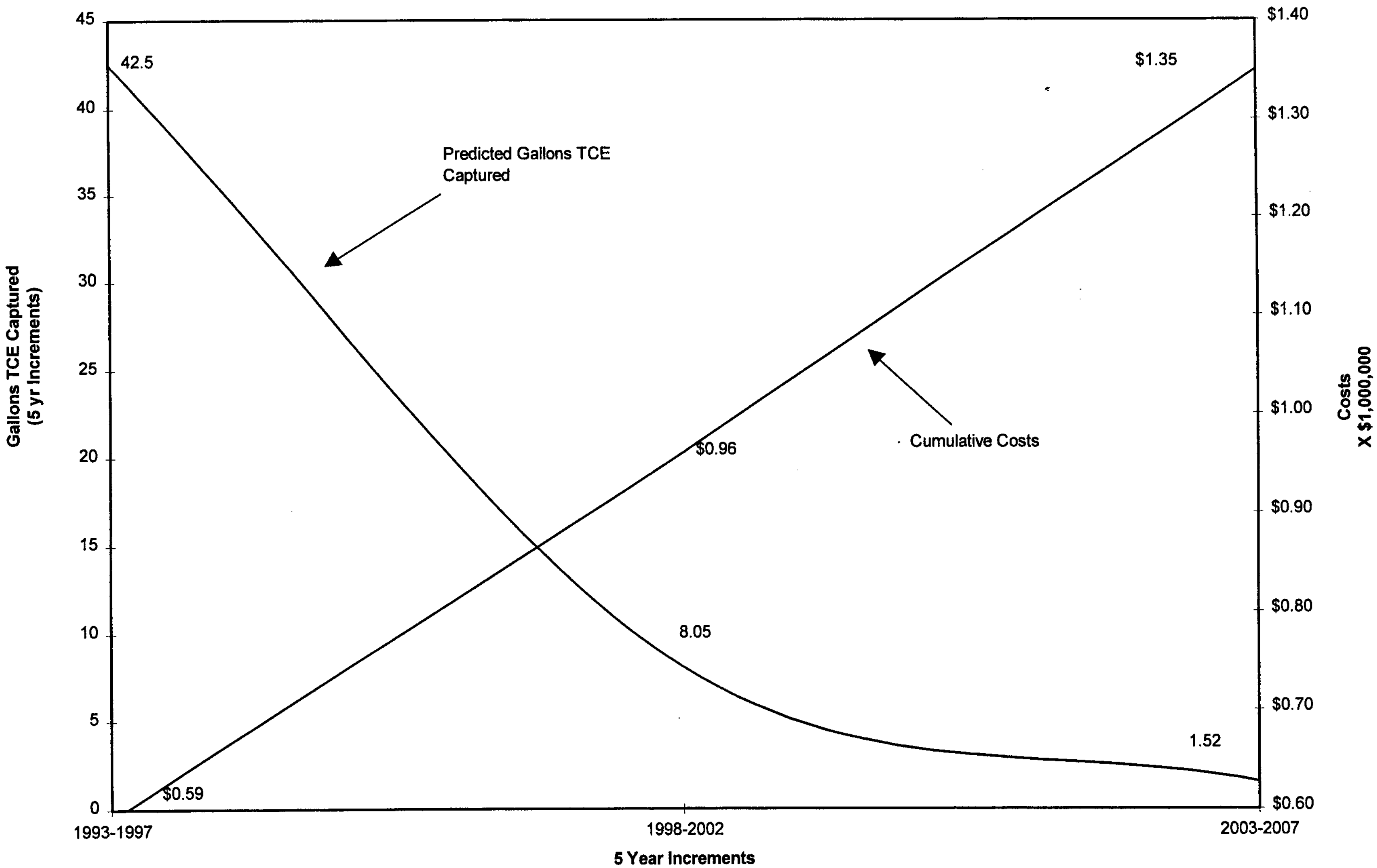


Figure 9. Lifetime Excess Cancer Risk VS Cumulative Costs, Mission St. P&T, Wurtsmith AFB

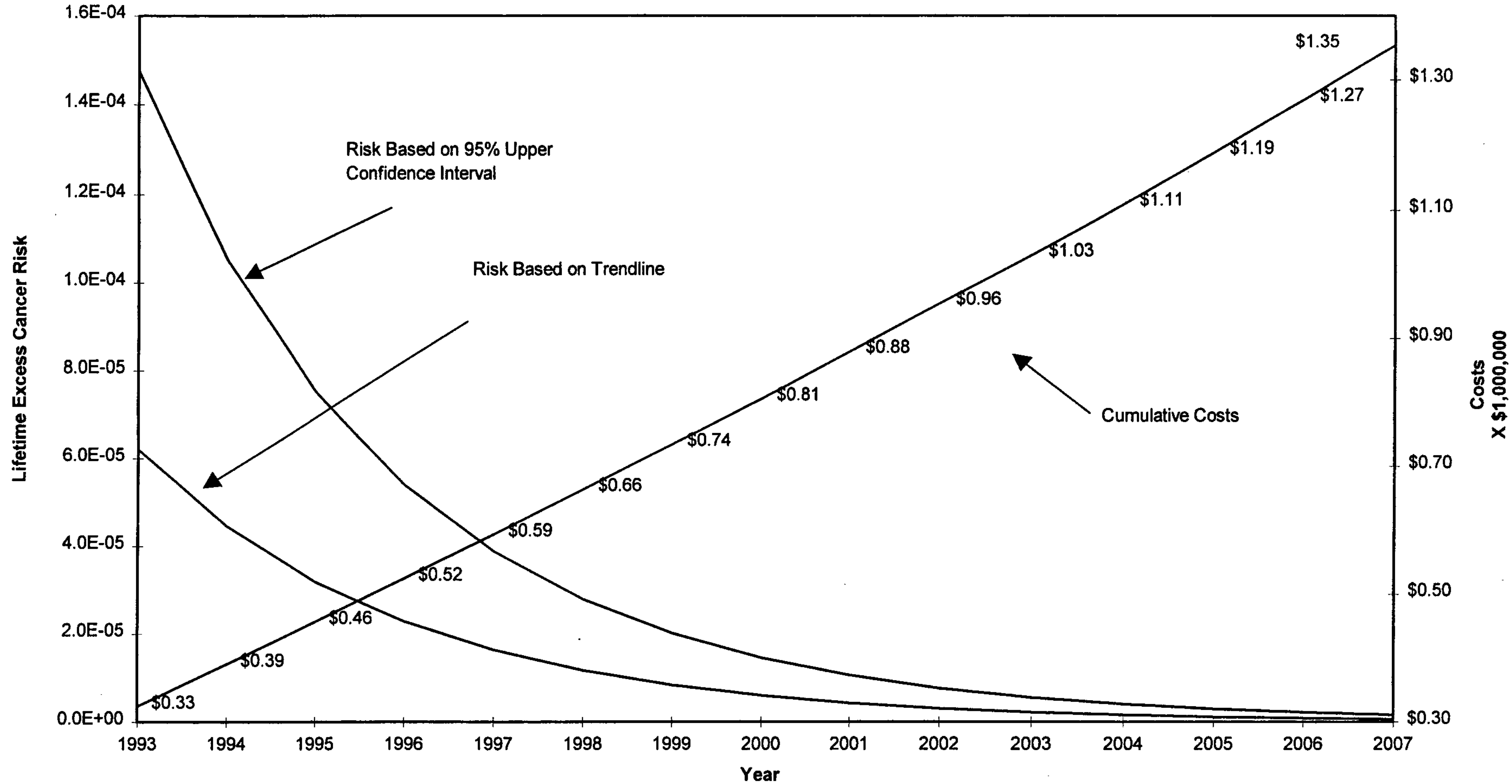


TABLE 4. COSTS AND RISKS AT DIFFERENT CLEANUP GOALS

TCE Concentration (ppb)	Year Achieved	Price/Gal TCE (that year)	Cumulative Costs	TCE Captured (total gals)	Average Price / Gallon TCE	Average Range of Risks*
PLANT 44, OT-12						
100	2002	$38 K	$26 M	1,760	$15 K	1.5E-05 (5.1E-05)
50	2007	$71 K	$37 M	1,948	$19 K	7.1E-06 (2.6E-05)
5	2026	$764 K	$87 M	2,186	$40 K	7.0E-07 (4.6E-06)
WRIGHT PATTERSON AFB, LF-05						
100	1998	$492 K	$2.7 M	6.6	$409 K	7.5E-06 (3.4E-05)
50	2000	$2.1 M	$3.5 M	6.9	$507 K	4.1E-06 (1.8E-5)
5	2006	$6.5 M	$6.3 M	7.3	$863 K	7.1E-07 (3.6E-06)
WURTSMITH AFB, OT-24						
100	1997	$8 K	$593 K	42.5	$14 K	1.6E-05 (3.9E-05)
50	2000	$45 K	$956 K	50.6	$19 K	1.5E-05 (6.0E-06)
5	2007	$262 K	$1,353 K	52.1	$26 K	5.9E-07 (1.6E-06)
WURTHSMITH AFB, SS-17/21/47						
100	NA	NA	NA	NA	NA	NA
50	1996	$12 K	$1 M	31	$32 k	1.0E-05 (1.7E-05)
5	2041	$947 K	$6.8 M	97	$70 K	3.2E-07 (1.7E-06)

* Based on the Trend Line or Upper 95th Confidence Limit of the Trend Line (in parenthesis).

Figure 10. Cumulative Gallons TCE VS Cumulative Costs, Arrow St. P&T, Wurtsmith AFB

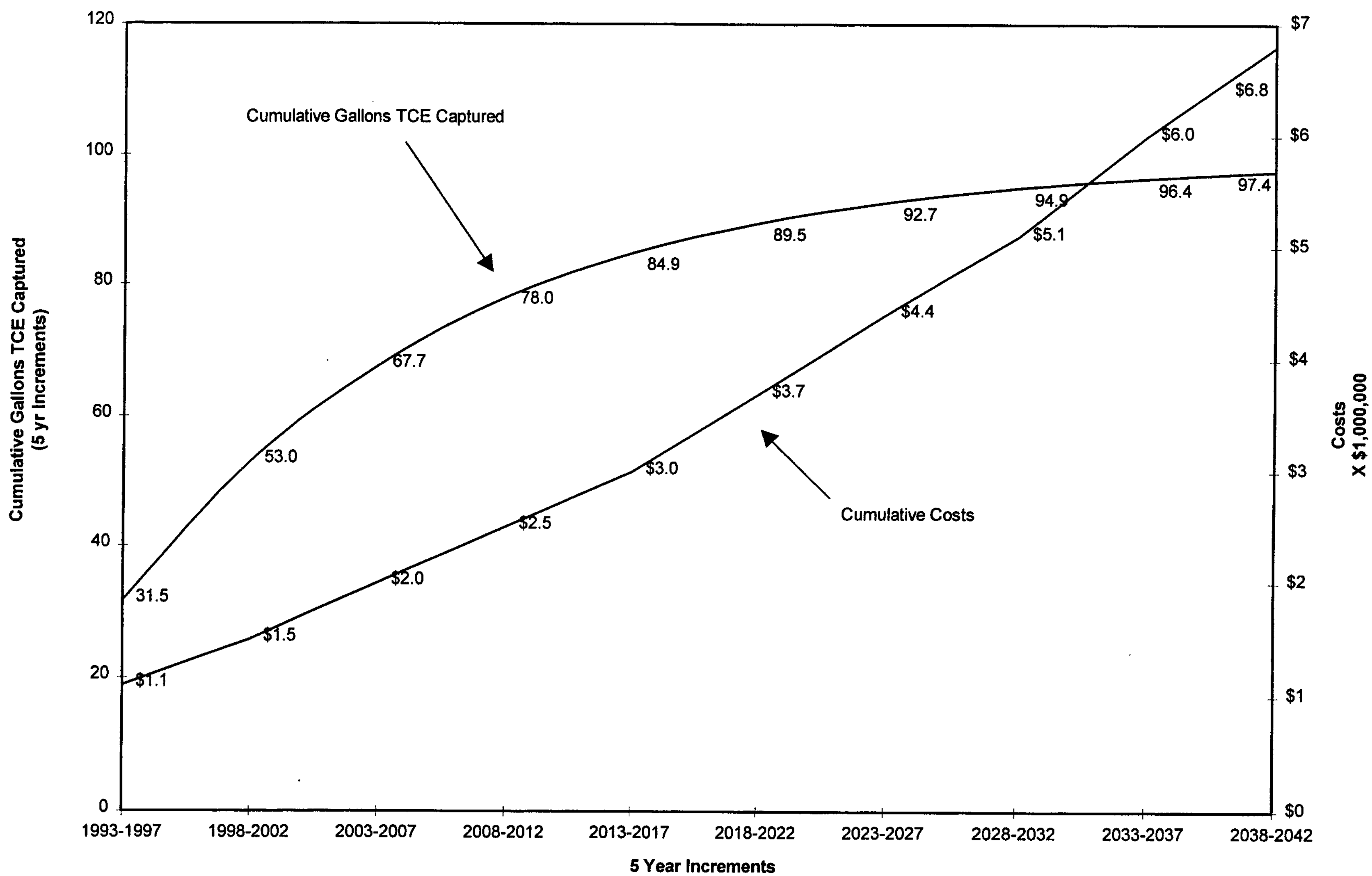


Figure 11. Gallons TCE Captured VS Cumulative Costs, Arrow St. P&T, Wurtsmith AFB

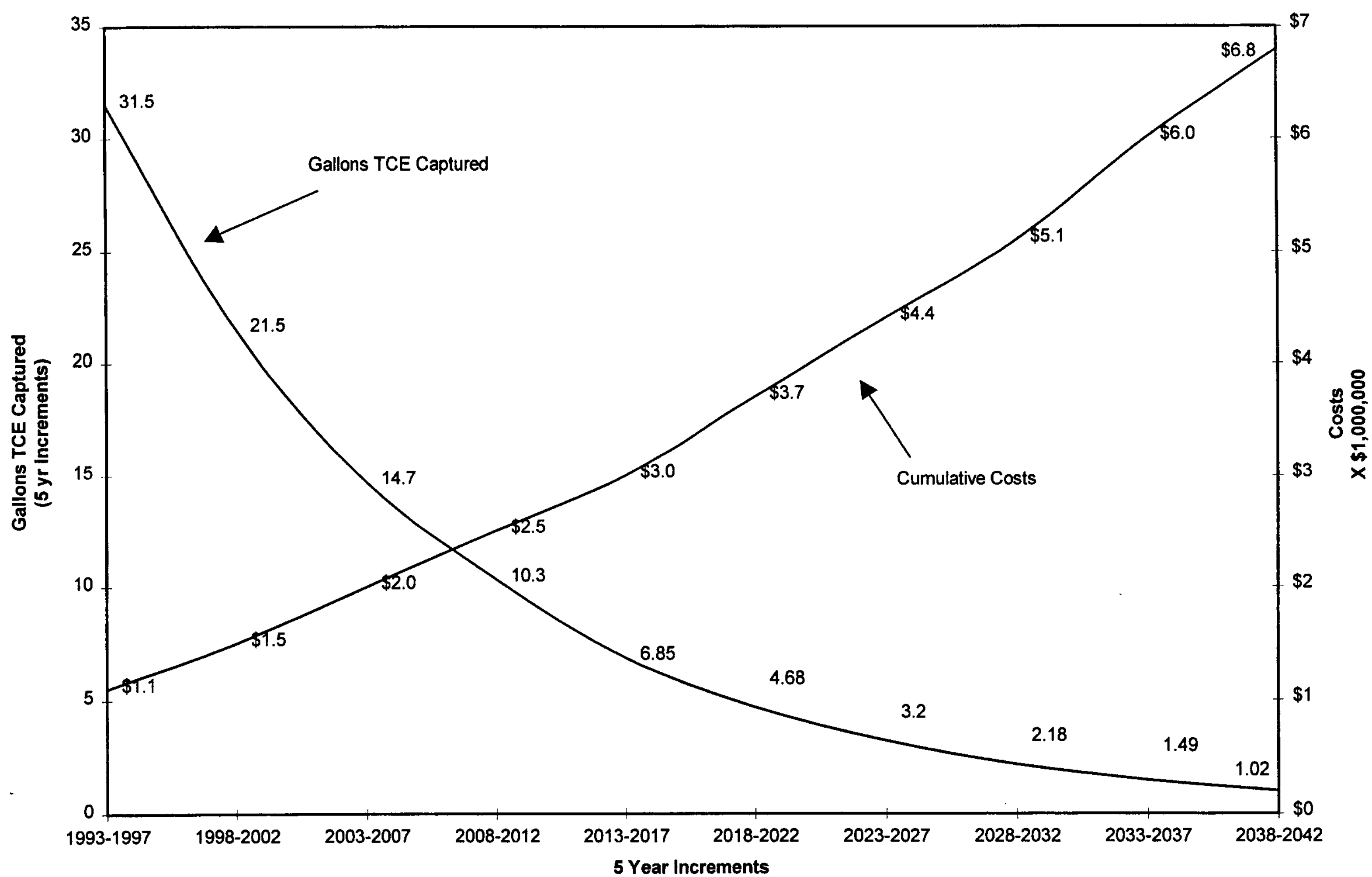
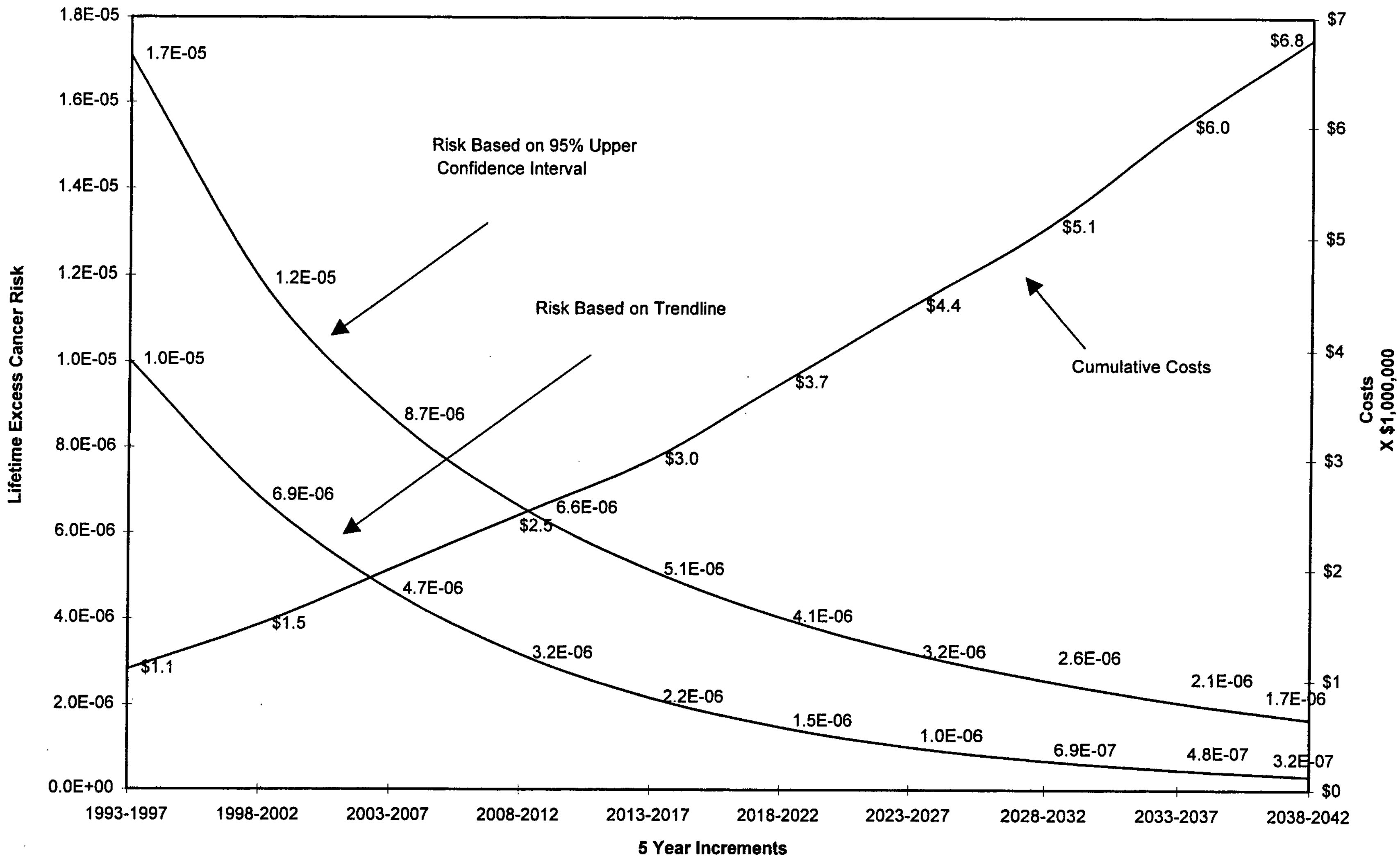


Figure 12. Lifetime Excess Cancer Risk VS Cumulative Costs
Arrow St. P&T, Wurtsmith AFB



CEA, OT-12, Plant 44

At Plant 44, a reduction in the contaminant level from 100 ppb to 50 ppb (50%) requires an increase in cost of approximately 39%, or approximately $205 thousand per each unit (ppb) of reduction in contamination. A reduction in the contaminant level from 50 ppb to 5 ppb (90% decrease) requires an increase in costs of approximately 139% or more than $1.1 million for each ppb of contaminant reduction.

For site OT-12, analytical data from nine individual monitoring wells was available. For this site the year in which each of the wells was expected to reach a given cleanup goal was statistically determined and an average of when all the wells would reach a given cleanup level was estimated. Therefore, not all the wells would reach a given goal simultaneously and the risk associated with the average time would not necessarily be equivalent to that associated with 5 ppb, 50 ppb, or 100 ppb concentrations. For OT-12, Plant 44, the UCI predicts that a TCE concentration of 100 ppb is likely to be reached in 2002. The range of Lifetime Excess Cancer Risk (LECR) associated with the trendline and 95% UCI of the trendline is 15 – 51 individuals per one million, respectively. It is predicted that the range of LECR will be 7.1 – 26 individuals per one million, based on when the trendline reaches 50 ppb and the 95% UCI of the trendline; and at 5 ppb the predicted LECR will range from 0.7 – 4.6 individuals per one million exposed. The cost to reduce one LECR per million population from 100 ppb to 50 ppb is predicted to fall between $410 thousand and $1.3 million. The cost to reduce one LECR per million population from 50 ppb to 5 ppb is predicted to be between $2.4 and $7.9 million.

CEA, LF-05, Wright Patterson AFB

At LF-05, a reduction in the contaminant level from 100 ppb to 50 ppb (50%) requires an increase in cost of approximately 30% or approximately $17 thousand per each ppb or unit of reduction in contamination. A reduction in the contaminant level from 50 ppb to 5 ppb (90% decrease) requires an increase in costs of approximately 76% or more than $60 thousand for each ppb of contaminant reduction.

For site LF-05, analytical data from four individual monitoring wells was available. As with OT-12, the year in which each of the wells was expected to reach a given cleanup goal was statistically determined and an average of when all the wells would reach a given cleanup level

was estimated. Therefore, not all the wells would reach a given goal simultaneously and the risk associated with the average time would not necessarily be equivalent to the risk associated with 5 ppb, 50 ppb, or 100 ppb concentrations. For this site, the UCI predicts that a TCE concentration of 100 ppb was likely to have been achieved in 1998. The range of Lifetime Excess Cancer Risk (LECR) associated with the trendline and 95% upper confidence interval of the trendline is 7.5 – 34 individuals per one million, respectively. It is predicted that the range of LECR will be 4.1 – 18 individuals per one million, based on when the trendline reaches 50 ppb and the 95% UCI of the trendline; and at 5 ppb the predicted LECR will range from 0.71 – 3.6 individuals per one million exposed. The cost to reduce one LECR per million population from 100 ppb to 50 ppb is predicted to be between $52 thousand and $244 thousand. The cost to reduce one LECR per million population from 50 ppb to 5 ppb is predicted at between $188 thousand and $798 thousand.

CEA, OT-24, Wurtsmith AFB

At Mission St. P&T a reduction in the contaminant level from 100 ppb to 50 ppb requires an increase in cost of approximately 36% or approximately $5 K per ppb reduction in contamination. A reduction in the contaminant level from 50 ppb to 5 ppb (90% decrease) requires an increase in costs of approximately 68% or more than $12 K for each ppb of contaminant reduction.

For OT-24, the UCI predicts that a TCE concentration of 100 ppb was likely to have been achieved in 1997. The range of Lifetime Excess Cancer Risk (LECR) associated with the trendline and 95% upper confidence interval of the trendline is 16 – 39 individuals per one million, respectively. It is predicted that the range of LECR will be 6 – 15 individuals per one million, based on when the trendline reaches 50 ppb and the 95% UCI of the trendline; and at 5 ppb the predicted LECR will range from 0.59 – 1.6 individuals per one million exposed. The cost to reduce one LECR per million population from 100 ppb to 50 ppb is predicted to be between $9 K and $21 K. The cost to reduce one LECR per million population from 50 ppb to 5 ppb is predicted to be between $41 K and $101 K.

The primary means of obtaining contaminant concentrations at this site and SS-17/21/47 is at the treatment system influent which is a combination of effluent from all the extraction wells.

Consequently, averaging of individual well information was not required. The statistical model used to develop the risk curves determines the years in which the site will reach the 3 contamination levels. The risk level is predicted to reach these levels sometime within the predicted year but the model predicts only in yearly increments. Consequently, the predicted level of risk at OT-24 and SS-17/21/47_may be slightly different than the expected risk associated with that of 5 ppb, 50 ppb, or 100 ppb TCE.

CEA, SS-17/21/47, Wurtsmith AFB

At Arrow St. P&T the influent contamination was under 100 ppb at the time the P&T system was installed. The cost to reduce one LECR per million population from 50 ppb to 5 ppb is predicted to be between \$375 K and \$592 K. For this site, the UCI predicts that a TCE concentration of 50 ppb was likely to have been achieved in 1996. The range of Lifetime Excess Cancer Risk (LECR) associated with the trendline and 95% upper confidence interval of the trendline is 10 – 17 individuals per one million, respectively. It is predicted that the range of LECR will be 0.32 – 1.7 individuals per one million, based on when the trendline reaches 5 ppb and the 95% UCI of the trendline. A reduction in the contaminant level from 50 ppb to 5 ppb (90% decrease) requires an increase in costs of approximately 54% or more than \$127 K for each ppb of contaminant reduction.

TABLE 5. COMPARISON OF COST EFFECTIVENESS ANALYSIS FOR FOUR SITES

Site	**Range of LECR/Million Population**			**Cost Range to Reduce 1 Unit of LECR Risk**		**Cost to Reduce 1 Unit of Contamination**	
	100 ppb	50 ppb	5 ppb	From 100 to 50 ppb	From 50 to 5 ppb	From 100 to 50 ppb	From 50 to 5 ppb
OT-12, AF Plant 44	15 to 51	7.1 to 26	0.7 to 4.6	\$410K to \$1.1M	\$2.4M to \$7.9M	\$205K	\$1.4M
LF-05, Wright-Patterson	7.5 to 34	4.1 to 18	0.71 to 3.6	\$52K to \$244K	\$188K to \$798K	\$17K	\$60K
OT-24 (Mission), Wurtsmith AFB	16 to 39	6 to 15	0.59 to 1.6	\$9K to \$21K	\$41K to \$101K	\$5K	\$12K
SS-17/21/47 (Arrow), Wurtsmith		10 to 17	0.32 to 1.7	NA	\$375K to \$592K	NA	\$127K

CONCLUSIONS

It is apparent from the data gathered and the forecast modeling performed that operating a P&T system to remediate an aquifer contaminated with TCE is an expensive, lengthy, and ineffective solution. It is also clear that attempting to remediate a TCE contaminated aquifer down to 5 ppb is often impossible to accomplish within a limited time frame with only limited funds to do so.

The EPA regulated TCE in drinking water in 1989 at a level of 5 ppb based on the results of animal bioassays. In establishing a drinking water MCL, EPA established a health goal of zero and set the enforceable MCL at 5 ppb based on the feasibility of detection at the time. The perceived increase in lifetime excess cancer risk involved by raising the TCE MCL from 5 to 50 or 100 ppb is justified by the millions of dollars which would be saved. By just considering the above 4 sites the cost savings realized from raising the TCE MCL from 5 to 50 ppb would be approximately $60 million and from 5 to 100 ppb would be approximately $72 million. At USAF installations alone there are 61 P&T sites where TCE is a contaminant and many more exist where remediation has not begun. If the average cost savings from the 4 sites was applied to the 61 TCE sites, an estimated $0.9 billion to $1.1 billion could be saved by raising the TCE MCL to 50 ppb or 100 ppb respectively. These are conservative figures as the four sites considered have decreasing contaminant concentration trends and many of the remaining TCE sites do not.

As mentioned earlier, currently one in two, or 0.5 of American males will contract cancer. This number theoretically increases to only 0.5000016 by exposure to 5 ppb TCE in drinking water over a lifetime. The billions saved by raising the MCL could better be used in cancer research, making our highways safer, or in a myriad of other more cost-effective uses.

RECOMMENDATIONS

To better address the problems associated with aquifers contaminated with TCE some or all of the following steps should be taken:

- This study should be expanded to include, at a minimum, an inventory of all the DoD P&Ts to gain better insight into the magnitude of the groundwater remediation problem faced by this country's military installations.

- The MCL for TCE should be based on science and not policy .

- Regulatory policy should differentiate between drinking and non-drinking water aquifers.
- Risk-based cleanup guidelines should be established which would define cleanup activities based on the potential risk involved at each site.

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Appendix A

Inventory of US Air Force Installation Pump and Treat Groundwater Remediation Systems

Inventory of all AF Pump and Treat Systems

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
AF Plant 3	LF-05	George Walters Environmental Engineer DSN 785-7716 X434	TCE 5 1,1-DCE 7 1,2-DCA 5 TCA 200	Shallow Tray Air Stripper	9508	100	yes	yes	Interim Action, not estimated	on TCE spreadsheet
AF Plant 4	OT-22 (East Parking Lot)	Rick Wice Program Manager IT Corp. 412/858-3309	TCE 400 (prevents TCE level in Paluxy Aquifer from exceeding 5)	Air Stripping and GAC	9405	550 (100ppb boundary)	source reduction action, not for containment	yes	2013	on TCE spreadsheet
AF Plant 4	SS-16 (Bldg 181)	Rick Wice Program Manager IT Corp. 412/858-3309	TCE 5 cis-1,2-DCE 70 trans-1,2-DCE 100	SVE, Dual Phase Extraction, Tray Air Stripper	9603	not known, removes GW on top of clay layers above large plume	yes	yes	2013	
AF Plant 4	FSA-1 (fuel saturation area)	Rick Wice Program Manager IT Corp. 412/858-3309	TCE 5, cis-1,2-DCE 70, trans-1,2-DCE 100, BTEX (no CU level, BRA stated levels do not cause excess risk)	O/W sep, Air Stripper, GAC	9210	60 (West plume of Terrace Alluvial)	not for containment	yes	2013	on TCE spreadsheet
AF Plant 4	LF-03 (Landfill #3)	Rick Wice Program Manager IT Corp. 412/858-3309	TCE 5 cis-1,2-DCE 70 trans-1,2-DCE 100	Air Stripping and GAC	9702	60 (West plume of Terrace Alluvial)	no, plume has enlarged	yes	2013	
AF Plant 44	OT-12	Capt. Hackathorn AFCEE Team Chief DSN 240-4176	TCE 5 DCE 7 TCA 200	Air Stripping and GAC	8704	440	yes	yes	2002	on TCE spreadsheet

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Andersen AFB	System pulls from several sites	Bill Oxford Booz-Allen AFCEE Technical Assistant 210/244-4244	TCE 5 PCE 5	Air Stripper	9702	currently not delineated	not known	yes	not established but expected to run for many years	System effluent is drinking water source
Andrews AFB	SS-01	Steve Richards IRP RPM DSN 858-3472	TCE 5	Air Stripper	system construction completed 9609 but awaiting regulator clearance to operate	3	NA	NA	2027	
Andrews AFB	SS-13	Steve Richards IRP RPM DSN 858-3472	POL 5,000	O/W Sep., Air Stripper, GAC	9601	3	yes	yes	2003	
Andrews AFB	FT-04	Steve Richards IRP RPM DSN 858-3472	POL 5,000	GAC	system construction completed 9604 but awaiting regulator clearance to operate	2	NA	NA	2000	
Andrews AFB	Bldg. 1845 (no IRP # assigned)	Steve Richards IRP RPM DSN 858-3472	POL 5,000	Bioslurper	9507	1	yes	yes	2000	
Arnold AFB	LF-03	Capt. Mike Hunter RPM DSN 340-6089	Benzene 5,000 TCE 5,000 MC 5,000 PCE 5,000 Vinyl Chloride 2,000	Air Stripping Tank, diffuser type	9501	20	yes	yes	2025	on TCE spreadsheet
Arnold AFB	LF-01	Capt. Mike Hunter RPM DSN 340-6089	TCE 200,000 PCE 5,000 1,1,1-TCA 5,000 1,1-DCE 5,000 1,1-DCA 5,000	Air Stripping, GAC, pH adjustment	9412	125	under study	yes	2024	on TCE spreadsheet

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Arnold AFB	WP-8	Capt. Mike Hunter RPM DSN 340-6089	1,1-DCE 10.01 PCE 5 1,1,1-TCA 5,000	Solvent Sep., Air Stripper, GAC, pH adjustment	9703	20	under study	yes	2027	
Arnold AFB	WP-6	Capt. Mike Hunter RPM DSN 340-6089	Benzene 5,000 1,2-DCA 5,000 1,1-DCE 7,000 MC 5,000 PCE 5,000 1,1,1-TCA 200,000 TCE 5,000 Toluene 1,000K	Air Stripper, GAC, pH adjustment	9611	360	under study	yes	2027	
Arnold AFB	SS-22	Capt. Mike Hunter RPM DSN 340-6089	TCE 5,000 1,1,1-TCA 200,000 1,1-DCA 5,000 1,1-DCE 5,000 Benzene 5,000 PCE 5,000 Toluene 1,000K	Air Stripper, GAC, pH adjustment	9611	300	under study	yes	2027	
Beale AFB	LF-13	Doug Coleman DSN 368-2667	TCE 5 cis-1,2-DCE 6 PCE 5	Air Stripper	9412	143	no, additional extraction wells being added	no	unknown	on TCE spreadsheet
Brooks AFB	FT-002	Roby Greg Environmental Engineer DSN 240-6716	TCE 5 and fuels, fuels CU level not established	UV/OX	9605	33	no, feasibility study almost complete, need more extraction wells	yes	2004-2005	
Castle Airport	OT-029 (OU-1)	Todd Lanning Environmental Engineer 209/726-4304	TCE 5 DCA PCE Vinyl Chloride	Air Stripping	9407	193	yes	no	2009	on TCE spreadsheet
Castle Airport	OT-30 (OU-2)	Todd Lanning Environmental Engineer 209/726-4304	TCE not established	GAC	9611	193 (both systems pulling from same plume)	yes	no	2016	
Chaunute AFB	ST-10	Virgil Krone Environmental Engineer 217/892-3240	gasoline Illinois UST regs Benzene 5	GAC	9609	2	yes	yes (has cleaned aquifer to DW	9708	

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
								standards)		
Davis Monthan AFB	ST-35	Karen Oden Chief of Restoration DSN 228-5595	BTEX EPA DW Stand. B 5 T 1,000 E 700 X 10,000	O/W Separator, 2 particulate bag filters, then Air Stripper	9510	0.7	yes	Cleanup Achieved, system shutdown 9602	completed 9602	
Eaker AFB	SWMU-21 (RCRA #)	Randal Looney Environmental Engineer 501/532-6550	fuel, BTEX not yet established	Bioslurper	9609	0.03	yes	yes	possibly by the end of 2000	currently removing free product, final action in place by end of FY98
Edwards AFB	ST-045	Bob Woods Chief of Restoration DSN 527-1407	BTEX and TCE no final ROD, remove contaminants down to level where nat. atten. can take over	Air Stripper, cat. ox. for vapors, GAC for polishing	9611	unknown	not trying to achieve containment, just lower conc. in hot spots, GW movement very slow	yes, system pulling out contaminants	unknown, nat. atten. will be final remediation mechanism	
Edwards AFB	ST-016	Bob Woods Chief of Restoration DSN 527-1407	BTEX and TCE no final ROD, remove contaminants down to level where nat. atten. can take over	Air Stripper, cat. ox. for vapors, GAC for polishing	9703	unknown	not trying to achieve containment, just lower conc. in hot spots, GW movement very slow	yes, system pulling out contaminants	unknown, nat. atten. will be final remediation mechanism	
Edwards AFB	ST-005	Bob Woods Chief of Restoration DSN 527-1407	BTEX and TCE no final ROD, remove contaminants down to level where nat. atten. can take over	Air Stripper, cat. ox. for vapors, GAC for polishing	9704	unknown	not trying to achieve containment, just lower conc. in hot spots, GW movement very slow	yes, system pulling out contaminants	unknown, nat. atten. will be final remediation mechanism	

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Edwards AFB	D-0015	Bob Woods Chief of Restoration DSN 527-1407	BTEX and TCE no final ROD, remove contaminants down to level where nat. atten. can take over	Air Stripper, cat. ox. for vapors, GAC for polishing	9704	unknown	not trying to achieve containment, just lower conc. in hot spots, GW movement very slow	yes, system pulling out contaminants	unknown, nat. atten. will be final remediation mechanism	
Eglin AFB	SS-01	Steve Williams Project Manager DSN 872-7791 X210	POL and Vinyl Chloride Benzene 1 Vinyl Chloride 1 Total Volatile Organics 50	Air Stripper	1990	0.25	partial contain-ment	no	2040	
Eglin AFB	OT-35	Steve Williams Project Manager DSN 872-7791 X210	Gasoline combined BTEX in 1,000s (unsure)	Air Stripper	1991	0.5	yes	no	2040	
Elmendorf AFB	ST-41	Larry Underbakke RPM DSN 317-552-1741	fuel oil EPA DW Stand. B 5 T 1,000 E 700 X 10,000	3 interceptor trenches, O/W Sep., Air Stripper	9310	1.2	yes	yes	9808	
Fairchild AFB	LF-02	Mark Connally, Bruce Oshita IRP DERA Chief DSN 657-5170	TCE 5	Air Stripping and GAC	9509	unknown	yes	yes	2025	on TCE spreadsheet
George AFB	GC-070	Bob Sommer BRAC Environmental Coordinator 619/246-5360	TCE not established	Air Stripper	9111	600	Phase II on line a short time, preliminary indications are they have containment	Phase II on line a short time, contaminants are being removed	2016	on TCE spreadsheet
Grissom ARB	ST-08	Valerie Stacy RPM 765/688-4595	JP-4 B 98.6 T 20,440 E 10,220 X 204,400	skimmer pump collecting free product	9310	0.5	yes	yes	2000	

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Hanscom AFB	FT-01, WP-11, WP-12	Thomas Best Environmental Engineer DSN 478-4495	1,1-DCA, 1,1-DCE, 1,2-DCE, PCE, TCE CU levels not established, going to risk based levels eventually	Air Stripping	9104	unknown	yes	CU levels not established but system is removing contaminants	2021	on TCE spreadsheet
Hanscom AFB	ST-21	Robert Spelfogel Environmental Engineer DSN 478-8207	Aviation Gas, Jet Fuel, #2 Heating Oil RI not complete	O/W Sep, sand filtration, GAC	9509	2 plumes combined less than 1 acre, RI not complete	yes, tight soils, primarily to collect free product	no, one plume has expanded	hope to shutdown in a year and nat. atten. thereafter	
Hill AFB	WP-07	Howie Aubertin Project Manager 801/775-3651	TCE 5, PCE 5 TCA 1,2-DCE Methylene Chloride, Toluene Beta-BHC Lindane	GAC	9303	27	yes	yes	2023	on TCE spreadsheet
Hill AFB	OT-26	Howie Aubertin Project Manager 801/775-3651	TCE 5 TCA 200 trans- 1,2-DCE 100 1,1-DCE 7	Air Stripper	9607	unknown	too early to tell	too early to tell	2006	
Holloman AFB	SS-59	Warren Ness IRP Chief 505/475-3931	JP-4 Removing free product only, remainder to natural attenuate	Air Stripper, Carbon Polishing	9607	8	yes	yes	free product removed 9801, GW and soil clean by 2001	
Kelly AFB	LF-012 LF-014 LF-015 (Zone 1)	Brian Stahl Zone 1 PM DSN 945-1815	TCE 5, trans-1,2-DCE 600, Vinyl Chloride 2, cis-1,2-DCE 600, Carbon Tet 5, Chlorobenzene 100	50% H_2O_2 & UV/OX	9311	45 14 3	no yes yes	yes yes yes	2023	on TCE spreadsheet

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Kelly AFB	SS-002 SS-042 E1R0 WP-022 (Zone 2)	Rhonda Hampton Zone 2 & 3 PM DSN 945-1815	TCE 5, PCE 5, Vinyl Chloride 2, cis-1,2-DCE 600, Toluene 1,000, Chloroethane 730, Chlorobenzene 100, trans-1,2-DCE 600	50% H2O2 & UV/OX	9311	141.4 9.0 .9 .3	yes yes yes yes	yes yes yes yes	2023	on TCE spreadsheet
Kelly AFB	SS-038 ST-006 SS-040 (Zone 3)	Rhonda Hampton Zone 2 & 3 PM DSN 945-1815	JP-4, TCE 5, PCE 5, Chlorobenzene 100	O/W Sep., metals precip., filtration, UV/OX	9602	426	yes yes no	yes yes no	2022	on TCE spreadsheet
Kelly AFB	SS-003 (Zone 5)	Rhonda Hampton Zone 2 & 3 PM DSN 945-1815	Benzene 5 Chlorobenzene 100	O/W Air Stripper	9503	591	no	yes	not been determined	on TCE spreadsheet
KI Sawyer AFB	DP-02	Mark Hansen Environmental Engineer 906/346-3090 X30	TCE 5 TCA 200 Benzene 5 Toluene 1,000 Ethylbenzene 700 Xylene 10,000	O/W sep., Air Stripper	9406	83.3	yes	installed to protect production water wells	unknown	on TCE spreadsheet
Langley AFB	ST-26	John Ties, IRP Program Manager, and Richard Jubie DSN 574-7193	JP-4 CU levels unknown	Air Stripper	9510	3.7	yes	yes	summer of 98	
Loring AFB	SS-04	Dennis Strange BEC 207/328-7082	Diesel Fuel and Heating Oil TPH 1,600	GAC	9511	unsure, no dissolved phase plume, only free product	yes	yes	9811	system has very low pump rate & only collects free product
Lowry AFB	GW OU-5 (didn't have IRP#)	Bill Jacobs BRAC Program Mgr. (Booz-Allen) 210/244-4239	TCE 5, breakdown products	Air Stripper	9611	160	yes	system strictly for containment	not established	

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
MacDill AFB	FT-23	Mark Canfield RPM 813/828-2567	POL Benzene 1 MPBE 50 Volatile Organic Aromatics 50	Air Stripper	9707	not yet defined	too early to tell	too early to tell	within 3 yrs	FL will allow them to shut down early before CU to long term monitor for nat. att.
MacDill AFB	ST-38	Mark Canfield RPM 813/828-2567	POL Benzene 1 MPBE 50 Volatile Organic Aromatics 50	O/W Separator then Air Stripper	9507	not yet defined	yes	yes	99	FL will allow them to shut down early before CU to long term monitor for nat. att.
March AFB	FT-33	John Satrom BEC 909/697-6722	JP-4 Benzene 5	Air Stripper and GAC	95	20	no, attainment being achieved by tight soils	yes	not established, system review in 2 years	
March AFB	FS-31	John Satrom BEC 909/697-6722	TCE 5 1,1-DCE 6 Bis(2-ethylhexyl)phthalate 4	GAC	92, major system modification 9706	1,280	yes	yes	no estimation	on TCE spreadsheet
Mather AFB	NPL-12 AC&W	Paul Bernheisel AFCEE Rep. 916/364-4007	TCE 5	Air Stripper	8502	36	yes	yes	2000	on TCE spreadsheet
McChord AFB	LF-05	David Burdette RPM DSN 984-3913	TCE 5 cis-1,2-DCE 70, 1,1-DCE .07, Vinyl Chloride .04	GAC	9402	40	yes	yes	2044	on TCE spreadsheet
McClellan AFB	HVTPE (High Vacuum Two-Phase Extraction)	Jim Caligiure 916/643-0830 X151	TCE 5 PCE 5 Methylene Chloride 5 Toluene 150	High Vacuum Two-Phase Extraction & GAC	91	230	no, currently in Phase I, Phase III in 2001 will complete containment	No cleanup levels established, system for containment	2034, new ROD probably extend it	on TCE spreadsheet

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
McClellan AFB	Bldg 336	Jim Caligiure 916/643-0830 X151	TCE 5 PCE 5 Methylene Chloride 5 Toluene 150	GAC	96	183	no, currently in Phase I, Phase III in 2001 will complete containment	No cleanup levels established, system for containment	2034, new ROD probably extend it	
McClellan AFB	Bldg. 431	Jim Caligiure 916/643-0830 X151	TCE 5 PCE 5 Methylene Chloride 5 Toluene 150	GAC	96	183	no, currently in Phase I, Phase III in 2001 will complete containment	No cleanup levels established, system for containment	2034, new ROD probably extend it	
McClellan AFB	Bldg. 621	Jim Caligiure 916/643-0830 X151	TCE 5 PCE 5 Methylene Chloride 5 Toluene 150	GAC	96	183	no, currently in Phase I, Phase III in 2001 will complete containment	No cleanup levels established, system for containment	2034, new ROD probably extend it	
McClellan AFB	DPE (Dual Phase Extraction)	Jim Caligiure 916/643-0830 X151	TCE 5 PCE 5 Methylene Chloride 5 Toluene 150	Dual Phase Extraction, Air Stripper	9707	183	no, currently in Phase I, Phase III in 2001 will complete containment	No cleanup levels established, system for containment	2034, new ROD probably extend it	
McClellan AFB	GTP (Groundwater Treatment Plant)	Jim Caligiure 916/643-0830 X151	TCE 5 PCE 5 Methylene Chloride 5 Toluene 150	UV/OX & LGAC	8705	390	no, currently in Phase I, Phase III in 2001 will complete containment	No cleanup levels established, system for containment	2034, new ROD probably extend it	on TCE spreadsheet
McConnell AFB	SS-03	Vern Imes IRP Manager DSN 743-3885	TCE 5	Air Stripper	9701	10	yes	too early to tell but systems are capturing contaminants	not established	very low pump rate, very tight soils, little migration
McConnell AFB	LS-11	Vern Imes IRP Manager DSN 743-3885	TCE 5	GAC	9610	2	yes	too early to tell but systems are capturing contaminants	not established	very low pump rate, very tight soils, little migration
Minneapolis-St. Paul Air Reserve Station	SS-07	Joanne Bentley Environmental Engineer DSN 783-1951	Aviation Gas B 5, T 1000, E 700, X 10000, MEK 4000, MIK 300, Acetone 700	free product recovery, air stripper	8801	free product plume .3	yes	yes	2005	

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Myrtle Beach AFB	SD-19	Richard Souza BEC 803/238-6119	TCE 5 1,2-DCE Vinyl Chloride	Air Sparging	9504	50	yes	yes	2005	on TCE spreadsheet
Nellis AFB	ST-27	Jim Pedrick, Chief of Restoration DSN 682-6103	JP-4, JP-8 not yet determined	Air Stripper	9511	system working 2 plumes, 25 & 100 acres	yes	yes	less than 20 yrs	
Norton AFB	CG-097 (CBA PAT)	Gerry Jungwirth Field Engineer 909/382-5064	TCE 5	Air Stripper, liquid phase GAC	9301	904, both systems working on same plume	no, plume has enlarged, not sure of extent	yes	originally 10-15 yrs but will exceed this	on TCE spreadsheet, Norton has 1 plume and 2 P&Ts
Norton AFB	CG-097 (BB PAT)	Gerry Jungwirth Field Engineer 909/382-5064	TCE 5	Air Stripper	9503	904, both systems working on same plume	no, plume has enlarged, not sure of extent	yes	originally 10-15 yrs but will exceed this	on TCE spreadsheet
Offutt AFB	LF-12	Dave Overbey 402/294-7621	TCE 50 DCE 20 Vinyl Chloride 5	GW extracted and pumped into sanitary sewer, no treatment	9611	15-17	not yet determined	goals not determined, no ROD	interim action, not determined	
Otis ANG	CS-4	Tim Forden Jacobs Engineering 508/564-5746	TCE, BCE, 1,1,2,2-TCE still negotiating, currently background concentration	GAC	9310	4.5	no, extraction wells not screened deep enough, TCE migrated below and past them	no, extraction wells not screened deep enough, TCE migrated below and past them	unknown, extraction well system must be modified before cleanup can be obtained	on TCE spreadsheet
Otis ANG	SD-5	Tim Forden Jacobs Engineering 508/564-5746	TCE Non-Detect	GAC	9708	20-30	too early to tell	too early to tell	another system to startup 9709	on TCE spreadsheet
Pease AFB	FDTA-2 (Site 8)	Kevin Thomas AFCEE Team Chief DSN 240-5271	POL, TCE NH GW Cleanup Stds. TCE 5	Air Stripper Catalytic Oxidation	9510	7.25	yes	yes	2010	on TCE spreadsheet

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Pease AFB	Site 32	Kevin Thomas AFCEE Team Chief DSN 240-5271	TCE no CU level, site is fractured bedrock, drove sheet pilings around it, system depresses water table and clean water flows in	GAC	9703	0.44	yes	no CU level established for this site	unknown	
Pease AFB	Site 81	Kevin Thomas AFCEE Team Chief DSN 240-5271	POL, TCE NH GW Cleanup Stds. TCE 5	Air Stripper, Catalytic Oxidation	9609	0.2	yes	purpose is to lower GW table for SVE	unknown	
Pease AFB	Zone 3	Kevin Thomas AFCEE Team Chief DSN 240-5271	TCE 5	GAC	9707	54	too early to tell	too early to tell	unknown	
Plattsburg AFB	FT-002	Brady Baker Environmental Engineer 518/563-2871	jet fuels and solvents, primarily TCE NYSDEC soil contaminants published in HWR-94-4046	Dual phase pumping, Air Stripper, sand filtration, GAC	9303, operated as a small pilot plant untill system was greatly expanded 9702	150	purpose is for free product recovery & depression of GW table to expose vadose zone	purpose is for free product recovery & depression of GW table to expose vadose zone	free product recovery complete 2-3 yrs, vadose zone cleanup by bioremediation & SVE 5-10 yrs	purpose of this system is to depress groundwater table to expose vadose zone to bioventing & SVE
Plattsburg AFB	SS-016	Brady Baker Environmental Engineer 518/563-2871	Acetone, MEK, TCE, DCE, other breakdown products CU level not established	Air Stripper	9701	5-10	treatability study, containment not a goal	no	not established	
Pope AFB	SS-07	Bob Bird RPM DSN 424-4194	JP-4 Interim Action, not determined	Bioslurping then to Oil/Water Separator	93	27.5 overall, 2 acre free product	yes at recovery trench	goals not established	free product removal in 2 years, no estimate of remainder	
Reese AFB	SS-02	Chris Morriss Project Manager DSN 838-5020	TCE 2 Carbon Tetrachloride 5	Air Stripper, GAC	9509	1,470	currently no, enhancement mods complete summer 98	yes	2023	

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Reese AFB	LF-03	Chris Moriss Project Manager DSN 838-5020	TCE 5	Air Stripper, GAC	9509	114	yes	yes	2023	
Seymour Johnson AFB	SS-04	Greg Ditzler Acting Technical Manager 919/736-6501	JP-4 Base & state are working to establish a risk based CU level	currently a skimmer and are installing a Bioslurper	9211	2	yes	system will operate for 5 yrs then be evaluated	2002	
Tinker AFB	OT-01 (Bldg. 3001)	Keith Buehler Project Engineer DSN 884-3058	TCE 5 1,2-DCE 5 1,2-DCA 5 Chlorobenzene 5	Air Stripping and GAC	9406	220	yes	yes	2022	on TCE spreadsheet
Travis AFB	SS-016	Mark Sandy Env. Engineer DSN 837-3739	TCE 5	GAC, UV/OX	9602	70	no, intended as a hot spot/source control system	goals not yet agreed to but contaminants being removed	2026	on TCE spreadsheet
Vance AFB	System currently pumping from SS-07, eventually also from ST-12	Donita Hazlett Assistant to IRP Chief DSN 448-6248	SS-07 TCE ST-12 TCE and Methlyene Chloride 5 for each	UV/OX	9701	SS-07 50 ST-12 not yet defined	no, more extraction wells and interceptor trench in 99	too early to tell	2004	
Vandenberg AFB	IRP Site 1	Jack Yamauchi Environmental Mgmt. DSN 276-1921	POL, BTEX B 29,000 T 63,000 E 8,100 X 179,000	GAC	9311	3	no	no	NA	Used for dewatering soil for Biovent system. Turned off 9510 and evaluated for nat. atten. Regulators do not agree to remediation by nat. atten. and they are currently reviewing regulator comments.
Wright Patterson AFB	LF-05	John Wolfe DSN 787-2201 X244	TCE 5 PCE 5 DCE 5	Air Sparging Tanks	9206	23	containing area for which it was designed, part of plume has migrated off base	yes	no estimation	on TCE spreadsheet

Installation	Site ID (IRP Site #)	Name and Title of POC	Contaminants and Cleanup Level (ppb)	Type P&T	Date System Operational	Size of Plume (acres)	System Achieving Containment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Comments
Wurtsmith AFB	SS-06 (Benzene Plant)	Paul Rekowski BRAC Environmental Coordinator 517/739-5161	Benzene 5	Air Stripper	9201	4	yes	yes	2004	
Wurtsmith AFB	OT-24 (Mission Drive)	Paul Rekowski BRAC Environmental Coordinator 517/739-5161	TCE 5	Air Stripper	8805	109	no, southern portion of plume being pulled by other systems	yes	2036	on TCE spreadsheet
Wurtsmith AFB	SS-17/21/47 (Arrow Street)	Paul Rekowski BRAC Environmental Coordinator 517/739-5161	TCE 5	Air Stripper, GAC as backup	8010	48	yes	yes	2012	on TCE spreadsheet

Appendix B

USAF TCE Contaminated Groundwater Sites Having P&T Systems with Historical Significance

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Contaminants & Concentration at Startup ppb		System Influent Concentration ppb		Type P&T	System Start-up yr/mo	Gallons of TCE Released	Period of Source Activity	Amount of TCE Captured Since Startup (gal)	Cost per Gal of TCE Captur-ed	System Const. & Modifica-tion Costs	Service Life of Major Compo-nents	Estimated Replace-ment Costs of Compo-nents	Yearly O & M Costs 1996
1	AF Plant 3 Tulsa, OK	LF-5 (landfill)	TCE	17,000	TCE	5	Shallow Tray Air Stripping	9508	unkn	unkn	6.6	198K	1,200K	20	200K	65K
			1,1-DCE	16,500	1,1-DCE	200										
			1,2-DCA	50	1,2-DCA	7										
			1,1,1-TCA	10,900	1,1,1-TCA	5										
2	AF Plant 4 (Ft Worth, TX)	OT-22 (east parking lot/flightline)	TCE	62,000	TCE	5,500	Air Stripping & Carbon Adsorption	9405	unkn	1942-1991	184	24.7K**	2,267.6 K	10	2,200K	89K
			cis-1,2-DCE	1,900	cis-1,2-DCE	2,000										
			trans 1,2-DCE	14												
			Benzene	46												
3	AF Plant 4 (Ft Worth, TX)	FSA-1 (Fuel Spill Area 1)	TCE	100-500	TCE	260	O/W Sep., Air Stripper, GAC	9210	unkn	mid 70's-early 80"s	0.8 (9604-9708)	176.6K**	1,093K	15	1,200K	85K
			trans-1,2-DCE	100-500	cis-1,2-DCE	96										
			Vinyl Chloride	100-500												
4	AF Plant 44	OT-12 (SP-344)	TCE	10,700	TCE	112	Air Stripping & Carbon Adsorption	8704	unkn	50's-70's	1,600	10,355	28,900 K	15	300K (repairs, replace-ment, preven-tive mainte-nance)	701K (1995)
			DCE	2,800	DCE	13										
			TCA	890	TCA	ND										
5	Arnold AFB	LF-3 (muni/ind landfill)	Benzene	18,000	Benzene	4.8	Air Stripping tank, diffuser type	9501	unknown	1971-1989	0.2	110K	250K	30	187K***	12K
			TCE	110,000	TCE	18.2										
			MC	78,000	MC	11.4										
			PCE	310,000	PCE	20										
			Vinyl Chloride	61,000	Vinyl Chloride	8.8 (9708)										

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Contaminants & Concentration at Startup ppb		System Influent Concentration ppb		Type P&T	System Start-up yr/mo	Gallons of TCE Re-leased	Period of Source Activity	Amount of TCE Captured Since Startup (gal)	Cost per Gal of TCE Captur-ed	System Const. & Modifica-tion Costs	Service Life of Major Compo-nents	Estimated Replace-ment Costs of Compo-nents	Yearly O & M Costs 1996
6	Arnold AFB	LF-1 (hazardous waste landfill)	TCE	13,000K	TCE	1,732	Air Stripping, Carbon Adsorption ,ph adjustment	9412	unkno wn	1956-1982	720	833.33	2,200K	30	1,650 K***	20K
			PCE	5,600K	PCE	704										
			TCA	2,800K	TCA	183										
			1,1-DCA	1,200K	1,1-DCA	35 (9708)										
7	Beale AFB	LF-13 (inactive landfill)	TCE	590	TCE	78	Air Stripping	9412	19	40's-60's	7.4	215,914	850K	10	86K	40K
			1,2-DCE	48												
			1,1,2 TCA	17K												
			PCE	7.6K												
8	Castle AFB	OT-29 (OU-1 MBS GW Plume, shallow HSZ)	TCE	550	TCE	120	Air Stripping	9407	495	1941-?	20.6 (startup-9610)	131K**	7,500K	20	5,625K* **	310K
			PCE		PCE	4.6										
			DCA													
			Vinyl Chloride		cis-1,2-DCE	5.7 (9609)										
9	Fairchild AFB	LF-02 (Craig Road Landfill)	TCE	1,800	TCE	290 (9612)	Air Stripping & Carbon Adsorption	9509	unkno wn	1950s-1970s	19.4 (captured in 1996)	23.5K* * (TCE captured in 1996)	7,800K	30	5,850K* **	190K
			1,2-DCE	130												
10	George AFB	GC-070 (NEDA NE disposal TCE Plume)	TCE	470	TCE	10	Air Stripping	9111	35.5	1941-1981	2.3	117K	4,900K	30	750K	300K

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Contaminants & Concentration at Startup ppb		System Influent Concentration ppb		Type P&T	System Start-up yr/mo	Gallons of TCE Re-leased	Period of Source Activity	Amount of TCE Captured Since Startup (gal)	Cost per Gal of TCE Captur-ed	System Const. & Modifica-tion Costs	Service Life of Major Compo-nents	Estimated Replace-ment Costs of Compo-nents	Yearly O & M Costs 1996
11	Hanscom AFB	3 sites, 1 system FT-01, WP-11, WP-12	TCE	3,730	TCE	400	Air Stripping	9104	4,876 (all conta mi-nants)	1) late 60s-1973 2) 1966-1972 3) early 1960s	426* (startup-9708)	28.7K** (TCE captured in 1996)	8,472K	30	6,354 K***	696K
			TCA	340	TCA	89										
			cis-DCE	600	cis-DCE	1,400 (9707)										
12	Hill AFB	WP-07 (DNAPL Recovery System OU 2)	TCE	890,000	TCE	485	Carbon Adsorption with Steam Stripping	9303	82,500	1967-1975	23,000	350	3,934K	30	4,500K	356K
			PCE	9,800	PCE	<25										
			TCA	33,000	TCA	<100										
			1,2-DCE													
			Methylene Chloride													
			Toluene													
			Beta-BHC													
			Lindane													
13	Kelly AFB	LF-012 LF-014 LF-015 (Zone 1)	TCE	13K,	TCE	70K	50% H2O2 & UV Oxidation	9311	unkno wn	unkno wn	330* (captured in 1996)	548** (TCE captured in 1996)	3,000K	30	2,250 K***	450K
			PCE	16K												
			Vinyl Chloride	260	Vinyl Chloride	42K										
			cis-1,2-DCE	23K	cis-1,2-DCE	192K										
14	Kelly AFB	SS-002 SS-042 E1R0 WP-022 (Zone 2)	TCE	490	TCE	50K	50% H2O2 & UV Oxidation	9311	unkno wn	early 70's-1982	1,094* (captured in 1996)	6** (TCE captured in 96)	3,500K	30	2,625 K***	450K
			PCE	5K	PCE	23K										
			Vinyl Chloride	18K	Vinyl Chloride	2.2K										
			1,2-DCE	50K	cis-1,2-DCE	60K										

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Contaminants & Concentration at Startup ppb		System Influent Concentration ppb		Type P&T	System Start-up yr/mo	Gallons of TCE Re-leased	Period of Source Activity	Amount of TCE Captured Since Startup (gal)	Cost per Gal of TCE Captur-ed	System Const. & Modifica-tion Costs	Service Life of Major Compo-nents	Estimated Replace-ment Costs of Compo-nents	Yearly O & M Costs 1996
15	Kelly AFB	SS-038 ST-006 SS-040 (Zone 3)	TCE	6.5K,	TCE	20K	O/W Sep, metals precip, filtration, UV OX	9206	unknown	unknown	104.4* (captured from 9701-9703)	121** (TCE captured 9701-9703)	4,000K	30	3,000 K***	450K
			PCE	31K	PCE	6K										
			Vinyl Chloride	840	Vinyl Chloride	1.5K										
			1,2-DCE	8.1K	1,2-DCE	1K										
16	KI Sawyer AFB	DP-02 (Drainage Pond #2)	TCE	1,000	TCE	27	Air Stripping, Catalytic Oxidation	9406	unknown	1960-1980	41	60K**	4,000K	15 (assumed)	3,000 K***	507.5K
			1,1,1-TCA	68												
17	March AFB	FS-31	TCE	1,400	TCE	33	Granular Activated Carbon (SVE system also)	9205	unknown	60s-70s	5	255K (includes SVE)	589K	15 (assumed)	442K***	420K (combined O&M, monitoring & SVE)
			1,2-DCE	260												
			Bisphthalate	63												
18	Mather AFB	AC&W	TCE	90-160	TCE	90-170	Air Stripping	9412	31	1918-1993	9.2 (startup-9611)	123.3K**	2,510K	15 (assumed)	1,882.5 K***	400K (O&M and Monitoring
19	McChord AFB	LF-05 (Base Landfill/Burn Trench)	TCE	82	TCE	16.5	Granular Activated Carbon	9402	>1.2g	1941-1972	1.16 8/96	$1,440K	770K (RD another 754K)	50	578K***	148K
			cis-1,2-DCE	210	cis-1,2-DCE	14										
			Vinyl Chloride	0.2	Vinyl Chloride	<1.3										
			1,1-DCE	1.8	1,1-DCE	<1.8										

TCE Sites Having Pump and Treat Systems with Historical Significance

<table>
<tr><th></th><th>Installation</th><th>Site ID (IRP Site #)</th><th colspan="2">Contaminants & Concentration at Startup ppb</th><th colspan="2">System Influent Concentration ppb</th><th>Type P&T</th><th>System Start-up yr/mo</th><th>Gallons of TCE Re-leased</th><th>Period of Source Activity</th><th>Amount of TCE Captured Since Startup (gal)</th><th>Cost per Gal of TCE Captur-ed</th><th>System Const. & Modifica-tion Costs</th><th>Service Life of Major Compo-nents</th><th>Estimated Replace-ment Costs of Compo-nents</th><th>Yearly O & M Costs 1996</th></tr>
<tr><td rowspan="4">20</td><td rowspan="4">McClellan AFB</td><td rowspan="4">GTP Groundwater Treatment Plant)</td><td>TCE</td><td>>1,000</td><td>TCE</td><td>381</td><td rowspan="4">Originally AS, now UV OX & LGAC</td><td rowspan="4">8705</td><td rowspan="4">5,000 base-wide</td><td rowspan="4">1956-late 1970s</td><td rowspan="4">3,000 1/94</td><td rowspan="4">1,800 (1993)</td><td rowspan="4">21,500 K</td><td rowspan="4">15</td><td rowspan="4">3,090K</td><td rowspan="4">2,600K</td></tr>
<tr><td>PCE</td><td></td><td>PCE</td><td>4</td></tr>
<tr><td>1,2-DCA</td><td></td><td></td><td></td></tr>
<tr><td>cis-1,2-DCE</td><td></td><td>cis-1,2-DCE</td><td>43 (avg. in plume, not system influent)</td></tr>
<tr><td rowspan="6">21</td><td rowspan="6">McClellan AFB</td><td rowspan="6">OU B/C (HVTPE)</td><td>TCE</td><td rowspan="6">Com-bined VOC Concent ration 60,000</td><td>TCE</td><td>485</td><td rowspan="6">High Vacuum Two-Phase Extraction & GAC</td><td rowspan="6">91</td><td rowspan="6">5,000 base-wide</td><td rowspan="6">1936-1965</td><td rowspan="6">3,462 base-wide 9403</td><td rowspan="6">1,800 (9403)</td><td rowspan="6">5,300K</td><td rowspan="6">15</td><td rowspan="6">365K</td><td rowspan="6">1,270K 1993</td></tr>
<tr><td>cis-1,2-DCE</td><td>cis-1,2-DCE</td><td>10</td></tr>
<tr><td>PCE</td><td>PCE</td><td>72</td></tr>
<tr><td>1,2-DCA</td><td>1,2- DCA</td><td>0.5</td></tr>
<tr><td></td><td>Methylene Chloride</td><td>2</td></tr>
<tr><td></td><td>Toluene</td><td>1.4 (avg. in plume, not system influ-ent)</td></tr>
</table>

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Contaminants & Concentration at Startup ppb		System Influent Concentration ppb		Type P&T	System Start-up yr/mo	Gallons of TCE Re-leased	Period of Source Activity	Amount of TCE Captured Since Startup (gal)	Cost per Gal of TCE Captur-ed	System Const. & Modifica-tion Costs	Service Life of Major Compo-nents	Estimated Replace-ment Costs of Compo-nents	Yearly O & M Costs 1996
22	Myrtle Beach AFB	SD-19 (B324 engine shop solvent vat plume)	TCE	1,400	TCE	146	Air Sparging	9504	76-105	65-87	16.3	64K	1,335K	15	2,500K	79.5K
			1,2-DCE	2,190	1,2-DCE	420										
			Vinyl Chloride	100	Vinyl Chloride	16										
23	Norton AFB	CG-097 (CBA PAT)	TCE	91.5	TCE	24 (9703)	Air Stripper, liquid phase activated carbon	9301	174.4 (both systems at base on same plume)	1940's - 1960's	15.5	149K**	2,513K	15	1,885 K***	300K
24	Norton AFB	CG-097 (BB PAT)	TCE	26.7	TCE	6.6	Air Stripping	9503	174.4 (both systems at base on same plume)	1940's - 1960's	17.6	54K**	7,436K	15	5,577 K***	450K
25	Otis ANG	CS-4 (Chemical Spill #4)	TCE	62	TCE	4	Carbon Adsorption	9310	55-75	1940-1946 and 1955-1983	.4 (startup-9709, calculated assumption based on a P&T technical review)	1,987K**	2,162K	10	1,000K	141K
			PCE	24												
			1,1,2,2-TCA	4												

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Contaminants & Concentration at Startup ppb		System Influent Concentration ppb		Type P&T	System Start-up yr/mo	Gallons of TCE Re-leased	Period of Source Activity	Amount of TCE Captured Since Startup (gal)	Cost per Gal of TCE Captur-ed	System Const. & Modifica-tion Costs	Service Life of Major Compo-nents	Estimated Replace-ment Costs of Compo-nents	Yearly O & M Costs 1996
26	Pease AFB	FDTA-2 (Site 8)	TCE	(conc. not known but was told by Team Chief that influent conc. has changed little)	TCE	3	Air Stripper, Catalytic Oxidation	9510	unknown	1961-1988	0.05*	303.4K**	6,123K	15	system expected to run only 15 yrs	489K (1,827K total)
			BTEX		B	17										
					E	8										
					T	9										
					X	36										
			Vinyl Chloride		Vinyl Chloride	20										
27	Tinker AFB	OT-01 (Bldg 3001)	TCE	330K	TCE	4,000	Air Stripping, Carbon Adsorption, Hi Temp Steam	9406	unknown	50's-early 80's	550 of VOCs	$2,955	12,000 K	30	9,000 K***	830K
			PCE	1,200	PCE	210										
			1,2-DCE	4,600												
			1,2-DCA	700												
			Chloroben	940	Toluene	200										
28	Travis AFB	SS-016 (oil spill area)	TCE	175,000	TCE	1,500	Carbon Adsorption, UV/OX	9602	165	1943-1981	19	34K**	1,800K	15	1,350 K***	10.5K
29	Wright Patterson AFB	LF-05	TCE	770	TCE	56	Air Sparging tanks	9112 modified 9207	unknown	1945-1991	113 (startup-9703)	17K**	2,250K	30	1,687.5 K***	370K (includes O&M and Monitoring)
			PCE	62												
			1,2-DCE	45	1,2-DCE	17 (9702)										
			Vinyl Chloride	14												

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Contaminants & Concentration at Startup ppb		System Influent Concentration ppb		Type P&T	System Start-up yr/mo	Gallons of TCE Re-leased	Period of Source Activity	Amount of TCE Captured Since Startup (gal)	Cost per Gal of TCE Captur-ed	System Const. & Modifica-tion Costs	Service Life of Major Compo-nents	Estimated Replace-ment Costs of Compo-nents	Yearly O & M Costs 1996
30	Wurtsmith AFB	OT-24 (Mission Drive)	TCE	300	TCE	61 (9703)	Air Stripping	8805	unkno wn	1959-?	42.5* (captured from 9307-9703)	12,400**	600K	18	450K***	40.5K
31	Wurtsmith AFB	SS-17/21/47 (Arrow St.)	TCE	14,774	TCE	30	Air Stripping, GAC as backup	8010	unkno wn	1959-?	31.5* (captured from 9307-9703)	8.4K**	200K	30	1,000K	40.5K

* Amount of TCE captured determined by system TCE influent concentration and pumping rate, 100% capture assumed

** Cost/Gallon TCE captured determined by O&M, monitoring, and amortized system construction and modification costs. Where other contaminants are present, costs for TCE and its breakdown products were estimated as a portion of the costs

*** Estimated replacement cost is 75% of system construction and modification cost

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Monitoring Costs 1996	Size of Plume (acres)	System Achieving Contain-ment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Aquifer Hydraulic Conduct-ivity (ft/d)	Aquifer Saturated Thickness (ft)	Aquifer Trans-missi-vity (ft^2/d)	Aquifer Porosity	Aquifer Bulk Density g/cm^3	Total Organic Carbon %	Syste m Flow Rate (GPM)	Com-ments
1	AF Plant 3 Tulsa, OK	LF-5 (landfill)	60K	100	yes	yes	interim action, no estimate	0.0003-0.04	3-4	0.0009-0.16	0.05 (low lime-stone)	1.7	0.0001 (low lime-stone)	6	
2	AF Plant 4 (Ft Worth, TX)	OT-22 (east parking lot/ flight-line)	75K	550 (100ppb bound-ary)	source reduction action, not contain-ment	yes	2013	1.28	12	15.4	0.25	1.6 (avg. for sand)	0.004 (avg. for alluvial deposits)	21	
3	AF Plant 4 (Ft Worth, TX)	FSA-1 (Fuel Spill Area 1)	18.7K	60	not for contain-ment	yes	2013	6.8	10	68	0.25	1.6 (avg. for sand)	0.004 (avg. for alluvial deposits)	1	
4	AF Plant 44	OT-12 (SP-344)	68.5K	440	yes	yes	2002	30-150	avg. 70	2,100-10,500	0.31	1.81	0.0039	3,820	
6	Arnold AFB	LF-1 (hazard-ous waste landfill)	180K	125	under study	yes	2024	20-30	30	600-900	0.12-0.46	1.4 (silty sand and gravel)	0.0009		
7	Beale AFB	LF-13 (inactive landfill)	123K	143	no, additional extraction wells being added	no	unknown	70	100	7,000	.20-.40	1.4-1.8	.008-.05	80	
8	Castle AFB	OT-29 (OU-1 MBS GW Plume, shallow HSZ)	200K	193	Phase 1 complete-remove TCE from source area, Phase 2 will be complete in 98 and will focus on contain-ment	little reduc-tion in TCE concentra-tion ob-served	2014	260	5-50 avg. 27.5	7,150	20-30	1.38-1.60	0.2	403	

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Monitoring Costs 1996	Size of Plume (acres)	System Achieving Contain-ment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Aquifer Hydraulic Conduct-ivity (ft/d)	Aquifer Saturated Thickness (ft)	Aquifer Trans-missi-vity (ft^2/d)	Aquifer Porosity	Aquifer Bulk Density g/cm^3	Total Organic Carbon %	Syste m Flow Rate (GPM)	Com-ments
9	Fairchild AFB	LF-02 (Craig Road Landfill)	75K	124	yes	yes	2025	400 (sandy gravel)	70-130	28,000-52,000	0.3 (sandy gravel)	1.5 (sandy gravel)	0.1 (alluvial sand and gravel)	194-255	
10	George AFB	GC-070 (NEDA NE disposal TCE Plume)	150K	600	Phase II on line a short time, preliminary indications are they have contain-ment	Phase II on line a short time, contaminant s are being removed	2016	upper aquifer 1-39 lower 1	upper 0-85 lower 30-150	upper avg. 808 lower avg. 90	.20	1.71	upper .011 lower .016	650	
11	Hanscom AFB	3 sites, 1 system FT-01, WP-11, WP-12	100K (programed for 1998)	65.5 (includes all plumes in 3 aquifers)	yes	Cleanup level not established, will be driven by risk assessment	2201	surface 0.05-280 lower 0.05-125 bedrock 2-300	surface 15 lower 5-60 bedrock 100	surface 0.75-4,200 lower 0.25-7,500 bedrock 200-30,000	.2	1.8	0.04	266	
12	Hill AFB	WP-07 (DNAPL Recovery System OU 2)	25K	27	yes	yes	2023	6.22-34	12-30	172.8-806.4	25-35	1.76	0.3-1.9	6	
13	Kelly AFB	LF-012 LF-014 LF-015 (Zone 1)	500K	45 14 3	no yes yes	yes yes yes	2023	3-151	.5-8	1.5-1208	.25	1.4 (lower end of sand)	non detect	32.5	

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Monitoring Costs 1996	Size of Plume (acres)	System Achieving Contain-ment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Aquifer Hydraulic Conduct-ivity (ft/d)	Aquifer Saturated Thickness (ft)	Aquifer Trans-missi-vity (ft^2/d)	Aquifer Porosity	Aquifer Bulk Density g/cm^3	Total Organic Carbon %	System Flow Rate (GPM)	Com-ments
14	Kelly AFB	SS-002 SS-042 E1R0 WP-022 (Zone 2)	500K	141.4 9.0 0.9 0.3	yes yes yes yes	yes yes yes yes	2023	0.3-30	1-17	0.3-510	0.35	1.4 (lower end of sand)	0.0004 (lower end of alluvial sand)	50	
15	Kelly AFB	SS-038 ST-006 SS-040 (Zone 3)	500K	426	yes yes no	yes yes no	2022	Avg. 62	6-13 Avg. <8	434	0.35	1.4 (lower end of sand)	0.0004 (lower end of alluvial sand)	30	
16	KI Sawyer AFB	DP-02 (Drainage Pond #2)	44K	83.3	no	system installed to protect production water wells	no estimate	shallow area of aquifer 79-283, deep area 28-57	60-200	shallow avg. 17,195 deep avg. 29,865	0.25	1.83	0.01-0.5	764	
17	March AFB	FS-31	420K (combined O&M, monitoring & SVE)	23	yes	yes	no estimation	0.1-200 avg. 12	75	909	0272	1.8	0.004 (avg. for alluvial deposits)	150	
18	Mather AFB	AC&W	400K (O&M and Monitoring	36	yes	yes	2000	0.4-1.4	60-70	2,000	0.2	1.78 (mid-range of sand & gravel)	0.004 (mid-range of alluvial sand & gravel)	180	influent TCE concentra-tion has changed little
19	McChord AFB	LF-05 (Base Landfill/ Burn Trench)	35K	40	yes	yes	2044	54	75	4,050	0.15	1.6	0.1 (retarda-tion factor 2, advec-tion vel. 0.5 ft/d)	140	

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Monitoring Costs 1996	Size of Plume (acres)	System Achieving Contain-ment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Aquifer Hydraulic Conduct-ivity (ft/d)	Aquifer Saturated Thickness (ft)	Aquifer Trans-missi-vity (ft^2/d)	Aquifer Porosity	Aquifer Bulk Density g/cm^3	Total Organic Carbon %	System Flow Rate (GPM)	Com-ments
20	McClellan AFB	GTP (Ground-water Treatment Plant)	1,700K	390	no, currently in Phase I, Phase III in 2001 will complete contain-ment	No cleanup levels established	2034, new ROD probably push it back	17.7-20	(3 zones) 25, 25, 50	850 100-1,100 2,000	0.45	1.25	0.2	694	
21	McClellan AFB	OU B/C (HVTPE)	101K 1993	230	no, currently in Phase I, Phase III in 2001 will complete contain-ment	No cleanup levels established	2034, new ROD probably push it back	10	Zone A 35 B 65 C 65	A 100-900 B 250-500 C 500-2,000	0.35-0.45	1.2-1.3	0.001-0.003	2	
22	Myrtle Beach AFB	SD-19 (B324 engine shop solvent vat plume)	187K	31.3	yes	yes	2005	18.7	30-50	748	.27	1.4 (sand)	.00145	100	
23	Norton AFB	CG-097 (CBA PAT)	50K	904 (both systems at base on same plume)	no, plume has extended, not sure of extent	yes	originally 10-15 yrs but will exceed	940 (calculated from transmissi vity)	45	14,000-80,000 avg. 42,000	0.4	1.7	0.1	444	aquifer very hetero-geneous, both systems at base on same plume
24	Norton AFB	CG-097 (BB PAT)	70K	904 (both systems at base on same plume)	no, plume has extended, not sure of extent	Current System Interim Action	originally 10-15 yrs but will exceed	940 (calculated from transmis-sivity)	45	14,000-80,000 avg. 42,000	0.4	1.7	0.1	2,500	

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site #)	Monitoring Costs 1996	Size of Plume (acres)	System Achieving Contain-ment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Aquifer Hydraulic Conduct-ivity (ft/d)	Aquifer Saturated Thickness (ft)	Aquifer Trans-missi-vity (ft^2/d)	Aquifer Porosity	Aquifer Bulk Density g/cm^3	Total Organic Carbon %	System Flow Rate (GPM)	Com-ments
25	Otis ANG	CS-4 (Chemical Spill #4)	500K	180	no, extraction wells not screened deep enough, TCE migrated below and past them	no, extraction wells not screened deep enough, TCE migrated below and past them	unknown, extraction well system must be modified before cleanup can be obtained	200	250	50,000	0.33	2	0.0002		
26	Pease AFB	FDTA-2 (Site 8)	489K (816K total)	7.25	yes	System influent concentra-tion has changed little	2010	5	22	110	0.4 (avg. for sand)	1.7	0.002	23	low concentra -tion of TCE in aquifer, primary purpose is to remove fuel
27	Tinker AFB	OT-01 (Bldg 3001)	618.3K	220	yes	yes	2022	1.7-2.8	5-20	8.5-22.8	0.32	1.8	3.9	140	
28	Travis AFB	SS-016 (oil spill area)	100K	70	no, system used for source control	Cleanup goals not agreed to	2026	0.000005-88.3	5-40 (avg. 30)	16-1,053	0.18	1.8 (mid-range for sand & gravel)	0.004 (mid-range alluvial sand & gravel)	69	
29	Wright Patterson AFB	LF-05	370K (includes O&M and Monitoring)	4	containing area for which it was designed	yes	2005-2007	308-666	71-150	22,000-100,000	0.25-0.34	1.8 (mid-range for gravel)	0.004 (mid-range alluvial sand & gravel)	694	

TCE Sites Having Pump and Treat Systems with Historical Significance

	Installation	Site ID (IRP Site (#)	Monitoring Costs 1996	Size of Plume (acres)	System Achieving Contain-ment?	Progressing Toward Cleanup Goals?	Estimated Date to Achieve Cleanup	Aquifer Hydraulic Conduct-ivity (ft/d)	Aquifer Saturated Thickness (ft)	Aquifer Trans-missi-vity (ft^2/d)	Aquifer Porosity	Aquifer Bulk Density g/cm^3	Total Organic Carbon %	System Flow Rate (GPM)	Com-ments
30	Wurtsmith AFB	OT-24 (Mission Drive)	27.3K	109	no	yes	2036	avg. for deep wells 31.2 shallow wells 16.4	avg. 45	5,000-20,000	0.35 (specific yield .2)	1.4 (lower end of sand)	0.001 (lower end of alluvial sand)	183	
31	Wurtsmith AFB	SS-17/21/47 (Arrow St.)	36.4K	48	yes	yes	2012	75-310	avg. 45	5,000-20,000	0.35 (specific yield .2)	1.4 (lower end of sand)	0.001 (lower end of alluvial sand)	593	

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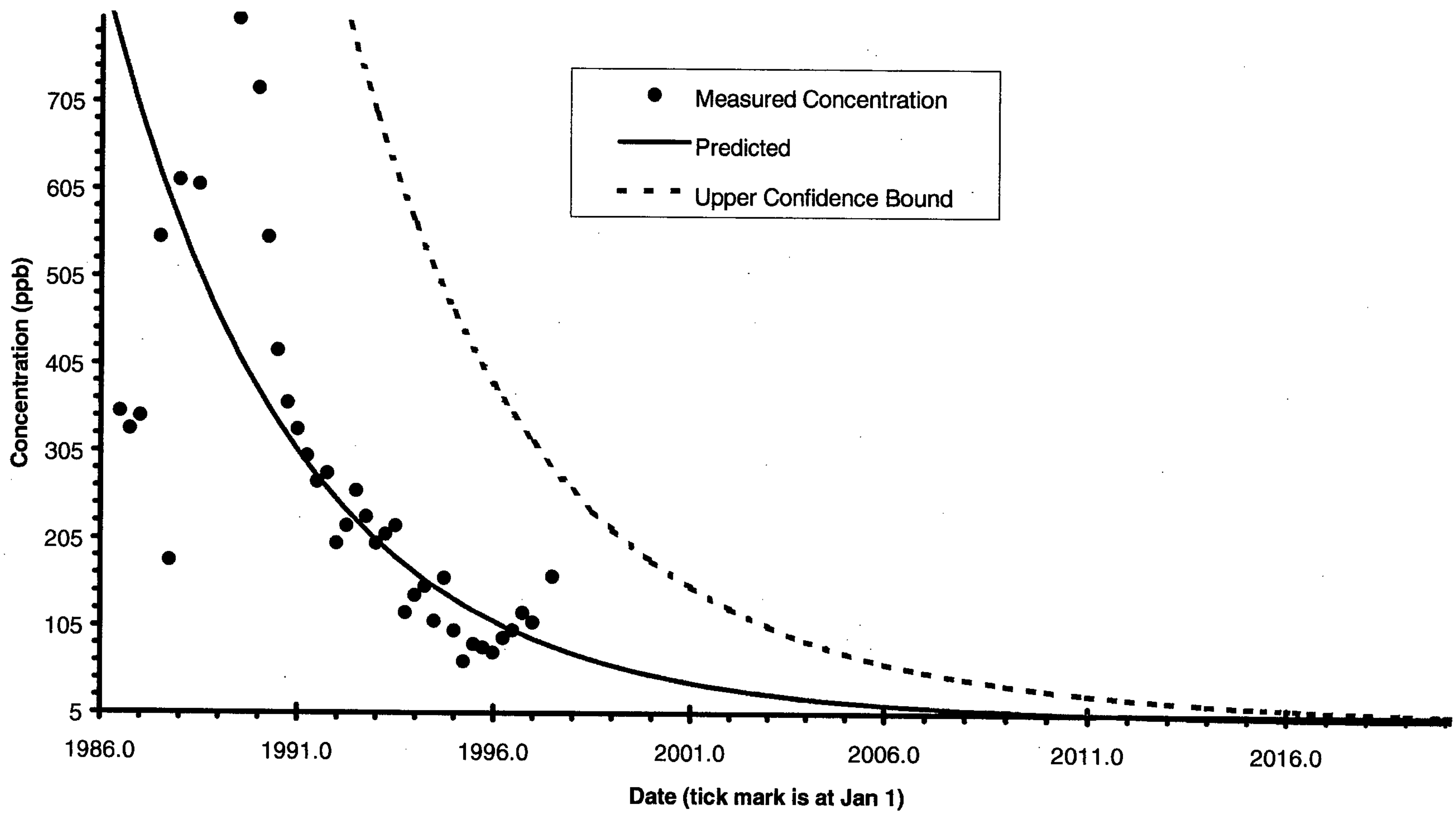
Appendix C

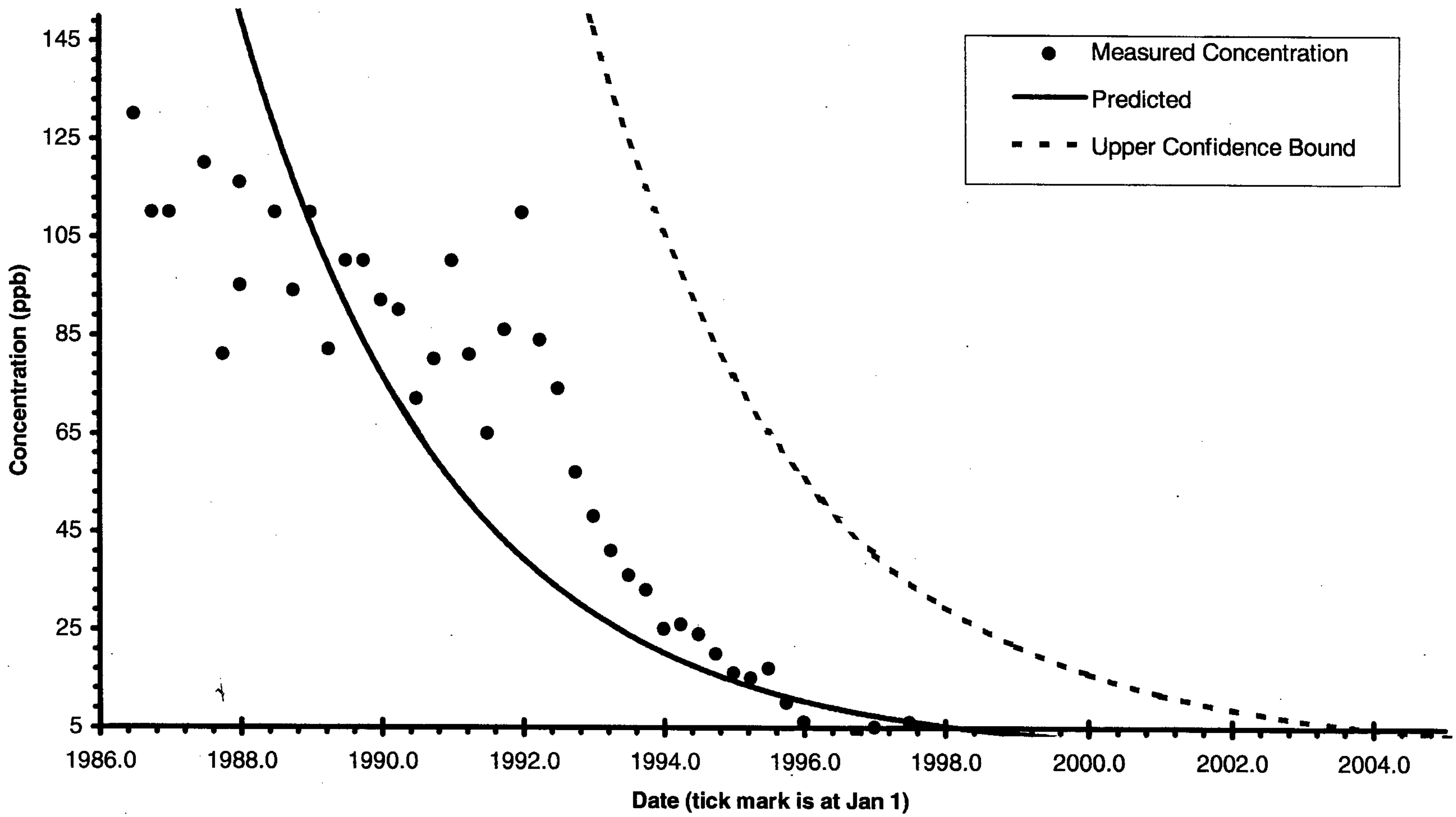
Observed and Predicted TCE Concentrations at 4 USAF P&T Sites

Figure 1. Observed and Predicted TCE Concentrations in Well M-23, Plant 44



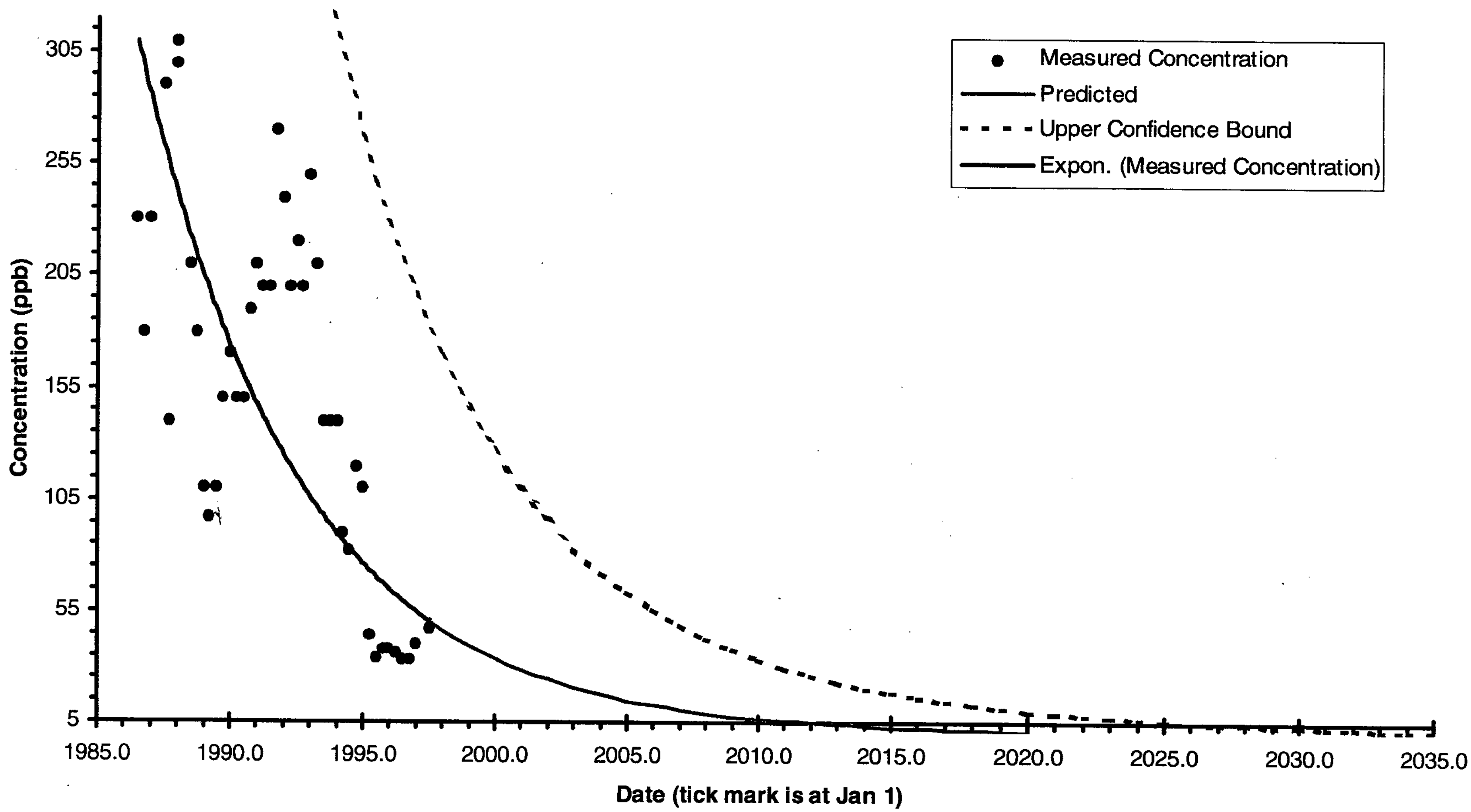
Predicted Concentration = exp(412.13 -0.2041*Year). Expected variation around the prediction is about +/- 60%. Based on 42 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 2. Observed and Predicted TCE Concentrations in Well M-25, Plant 44



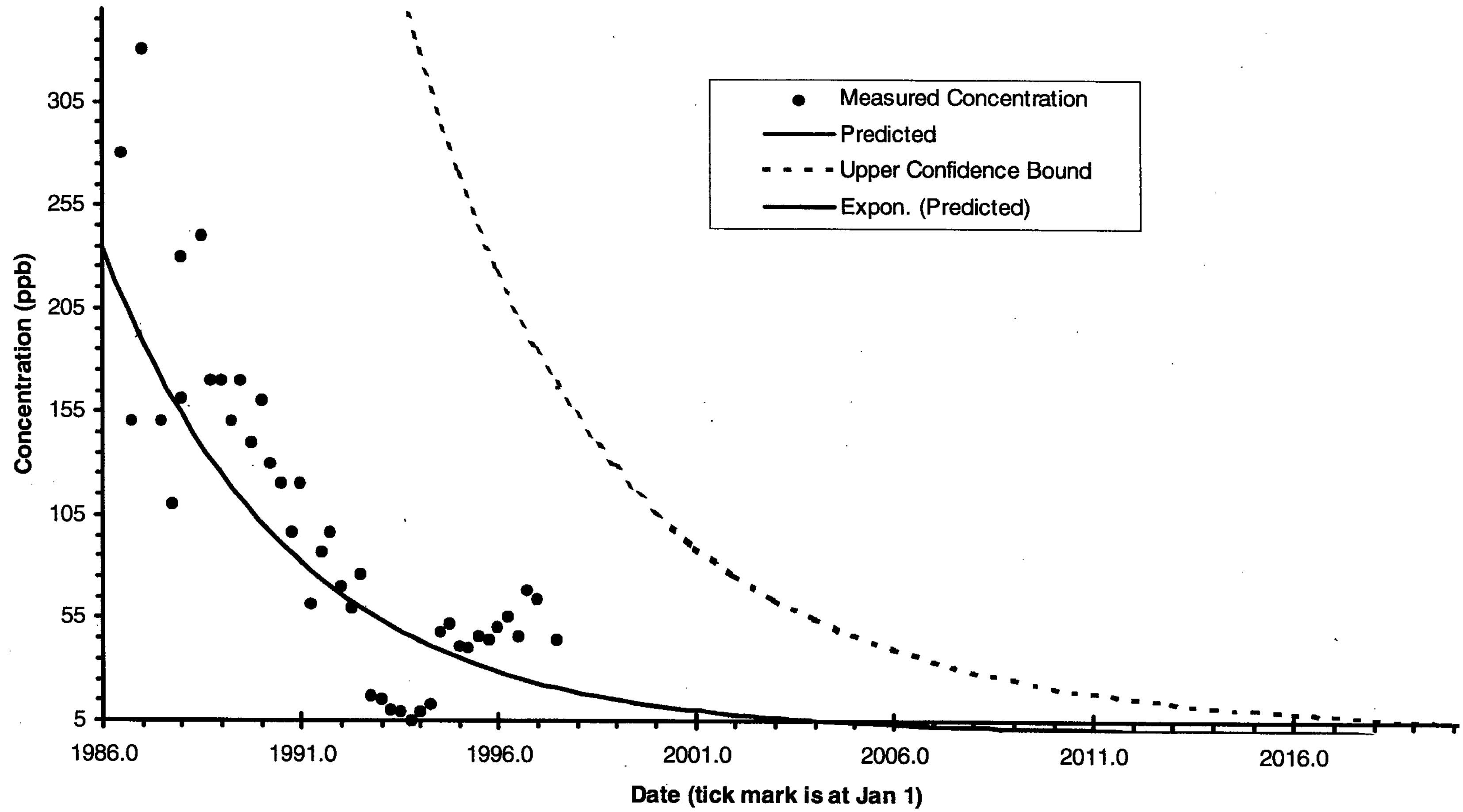
Predicted Concentration = exp(668.20 -0.3336*Year). Expected variation around the prediction is about +/- 81%. Based on 43 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 3. Observed and Predicted TCE Concentrations in Well M-2B, Plant 44



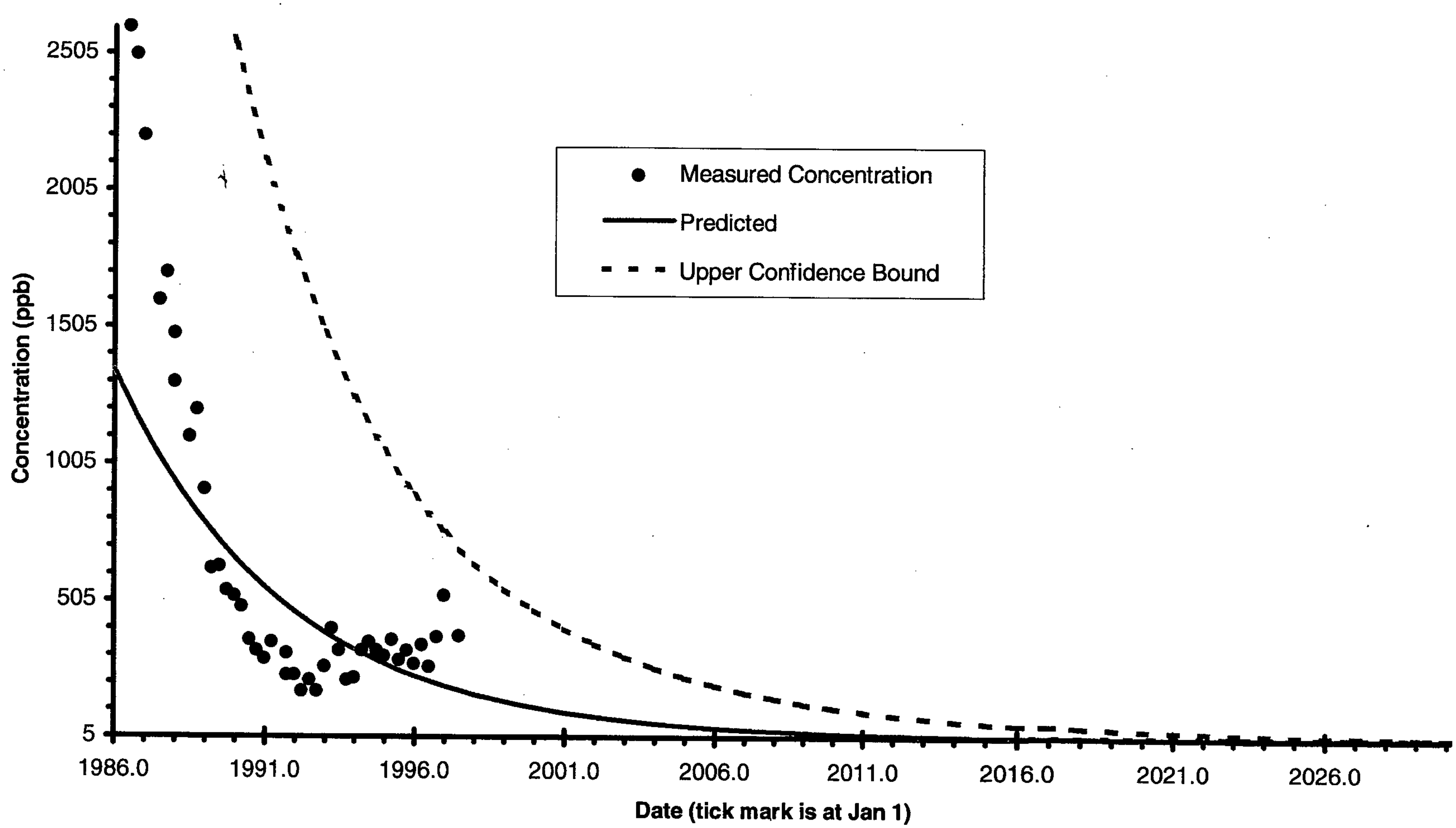
Predicted Concentration = exp(333.06 -0.1648*Year). Expected variation around the prediction is about +/- 61%. Based on 43 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 4. Observed and Predicted TCE Concentrations in Well M-3A, Plant 44



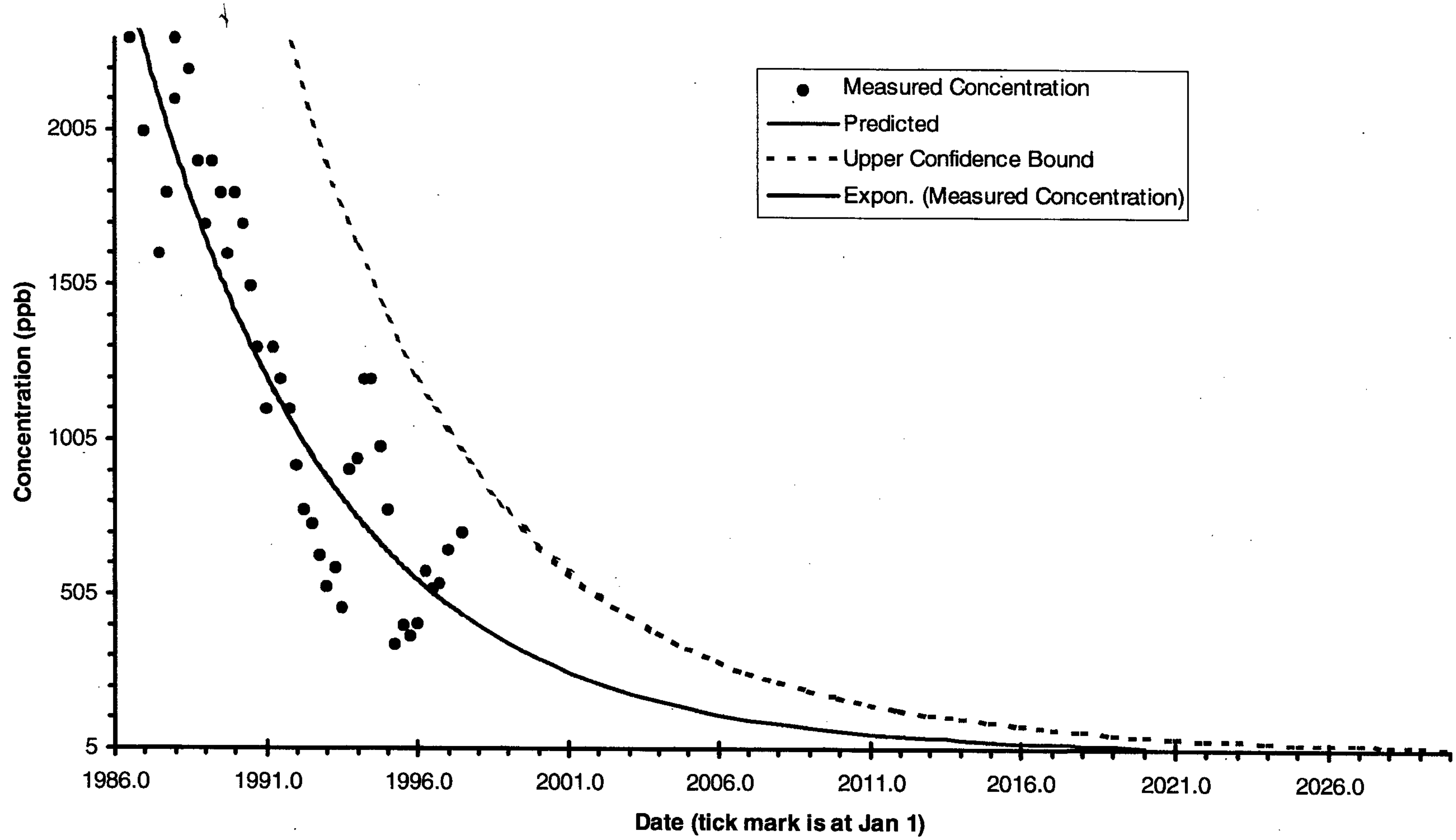
Predicted Concentration = exp(422.83 -0.2102*Year). Expected variation around the prediction is about +/- 99%. Based on 43 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 5. Observed and Predicted TCE Concentrations in Well M-41, Plant 44



Predicted Concentration = exp(359.71 -0.1775*Year). Expected variation around the prediction is about +/- 65%. Based on 43 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

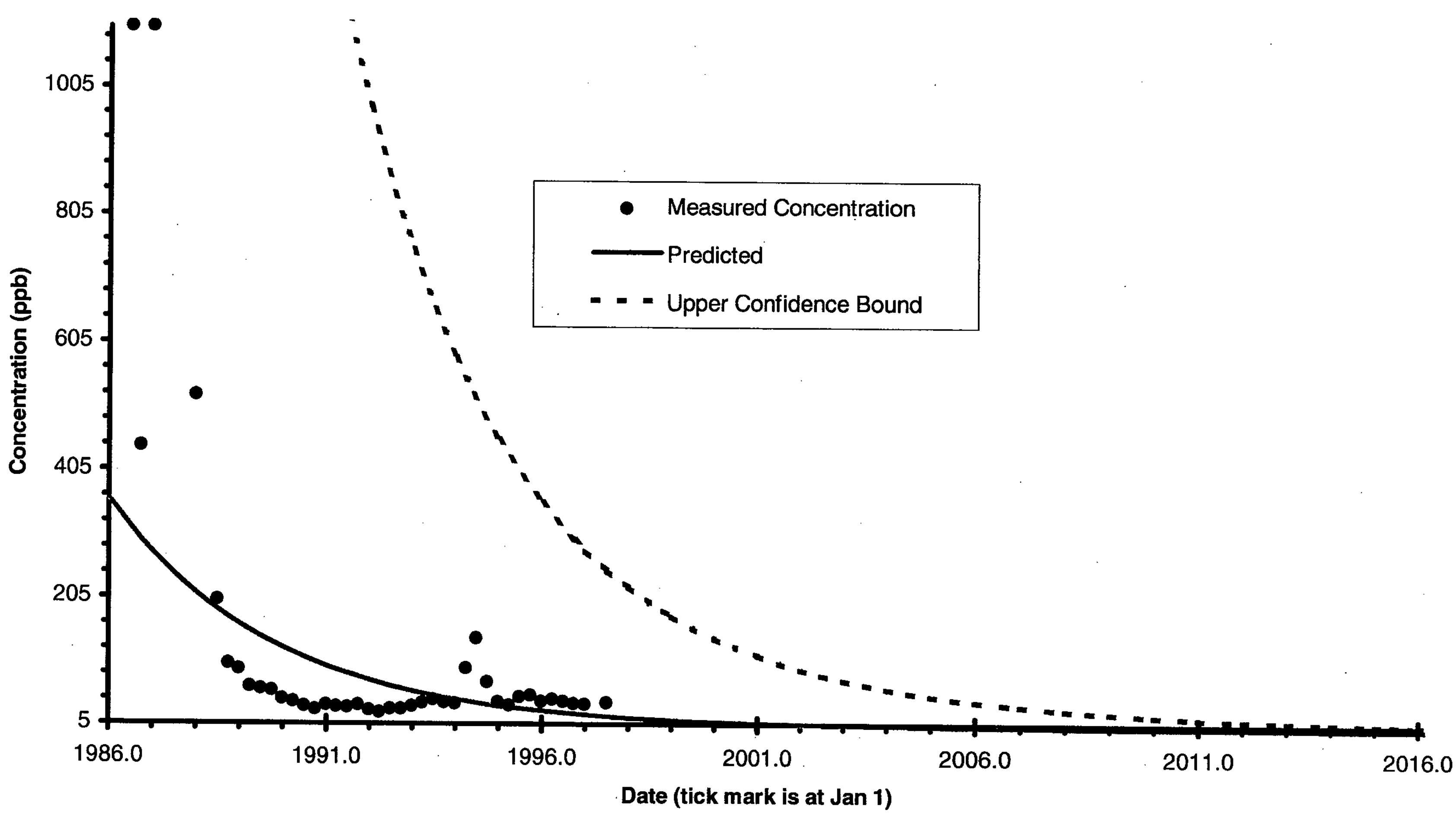
Figure 6. Observed and Predicted TCE Concentrations in Well M-5, Plant 44



Predicted Concentration = exp(320.71 -0.1575*Year). Expected variation around the prediction is about +/- 37%. Based on 42 measurements.

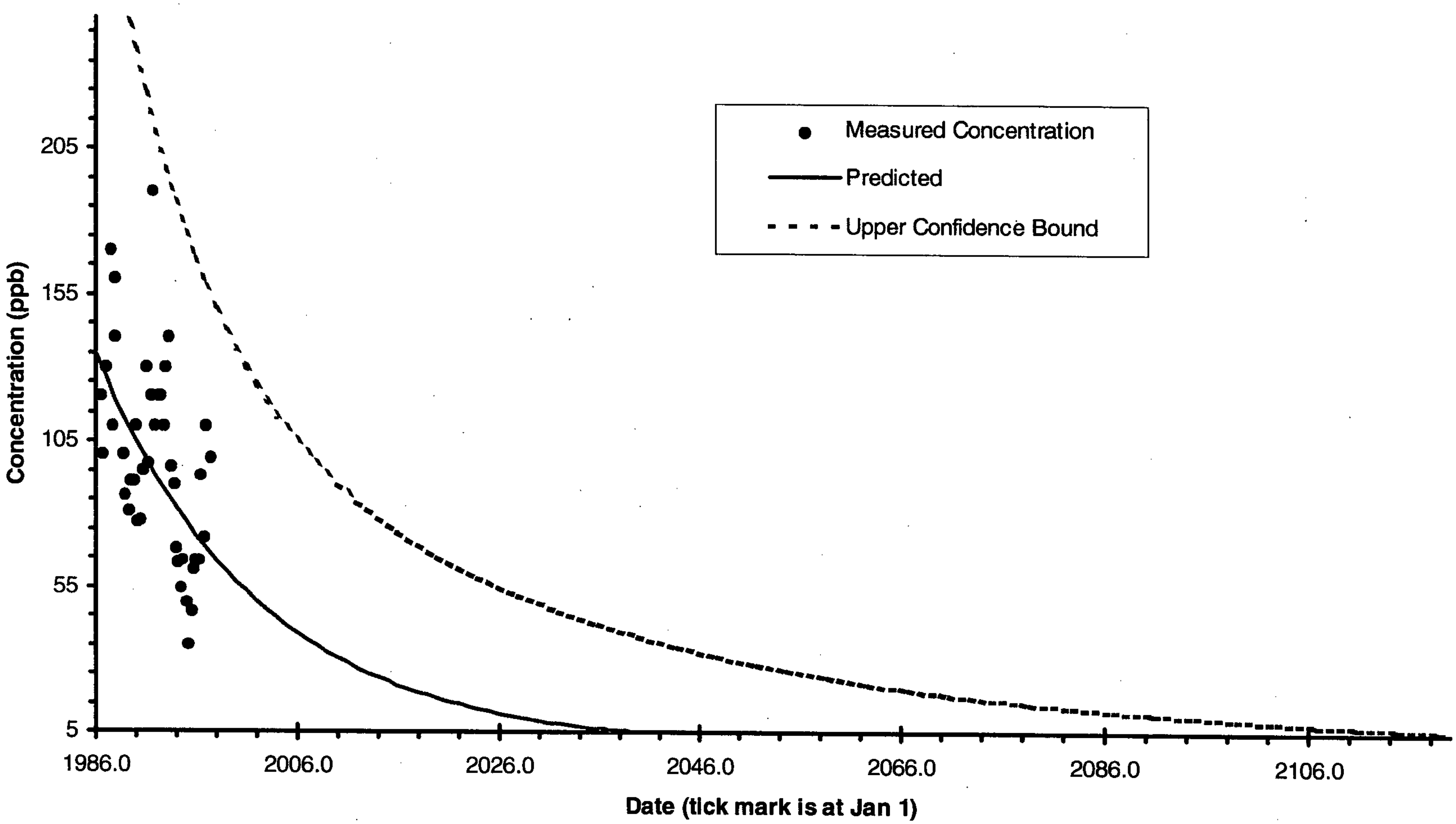
Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 7. Observed and Predicted TCE Concentrations in Well M-7, Plant 44



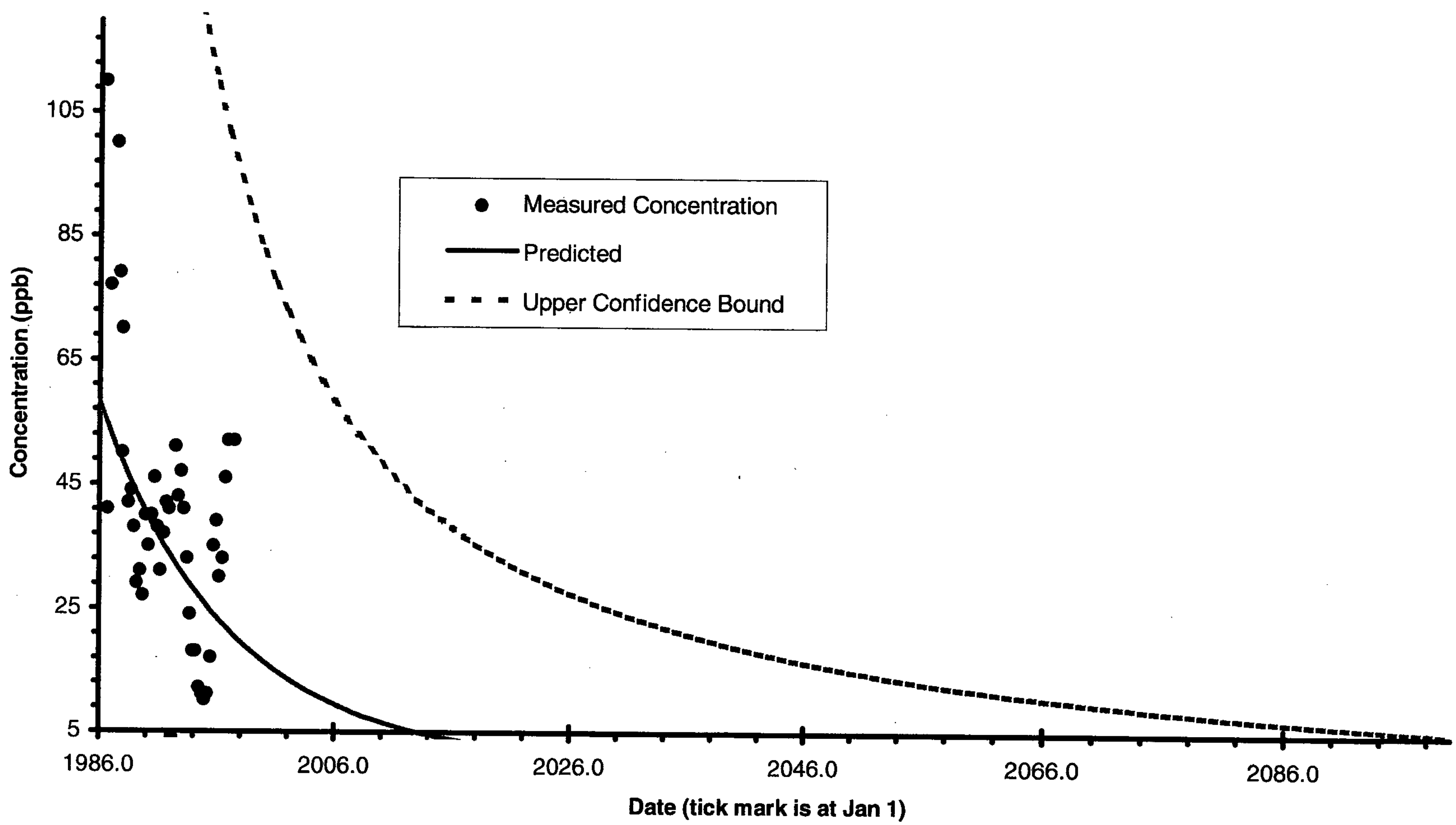
Predicted Concentration = exp(531.85 -0.2648*Year). Expected variation around the prediction is about +/- 127%. Based on 43 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 8. Observed and Predicted TCE Concentrations in Well M-8, Plant 44



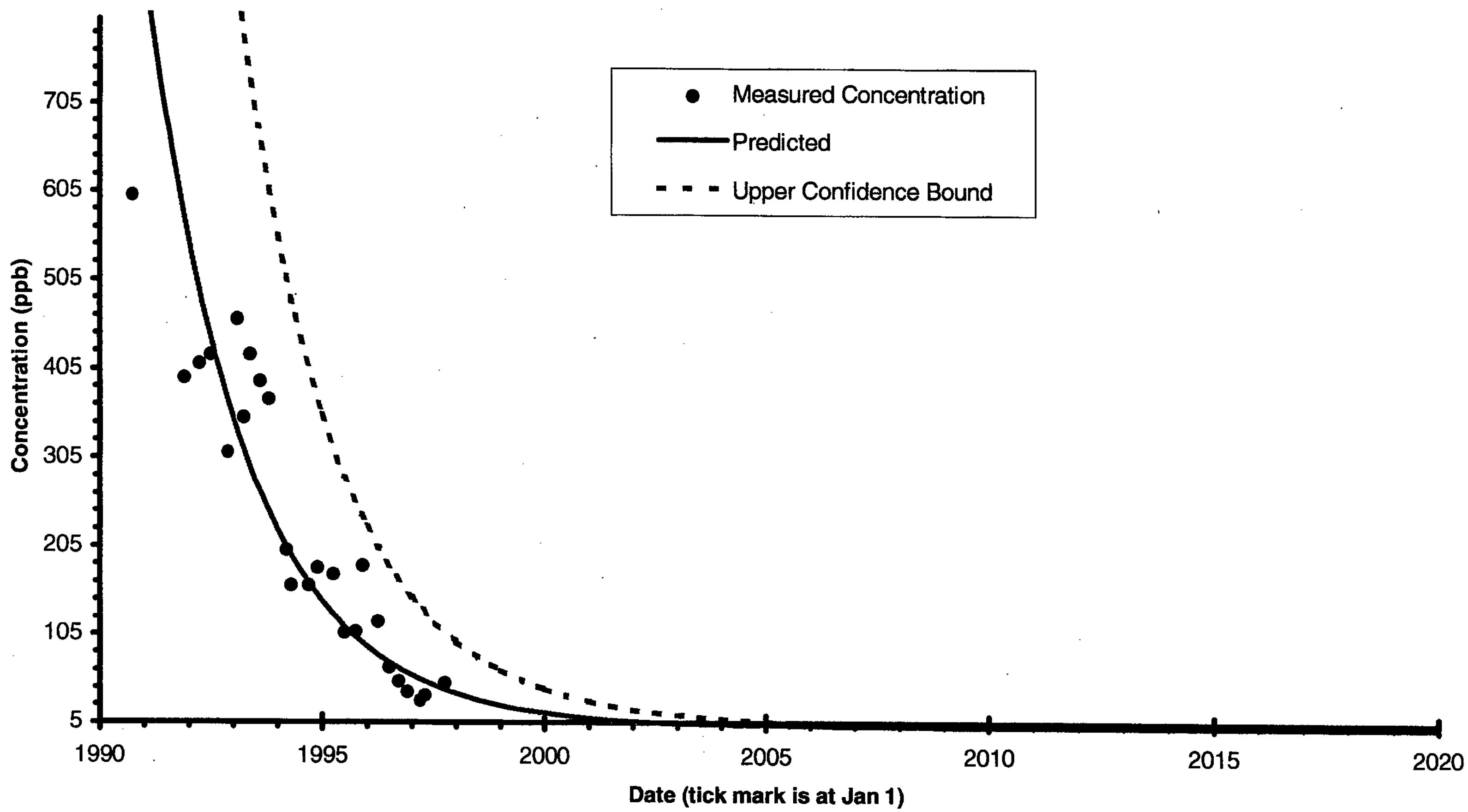
Predicted Concentration = exp(127.94 -0.0620*Year). Expected variation around the prediction is about +/- 40%. Based on 42 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 9. Observed and Predicted TCE Concentrations in Well M-9, Plant 44



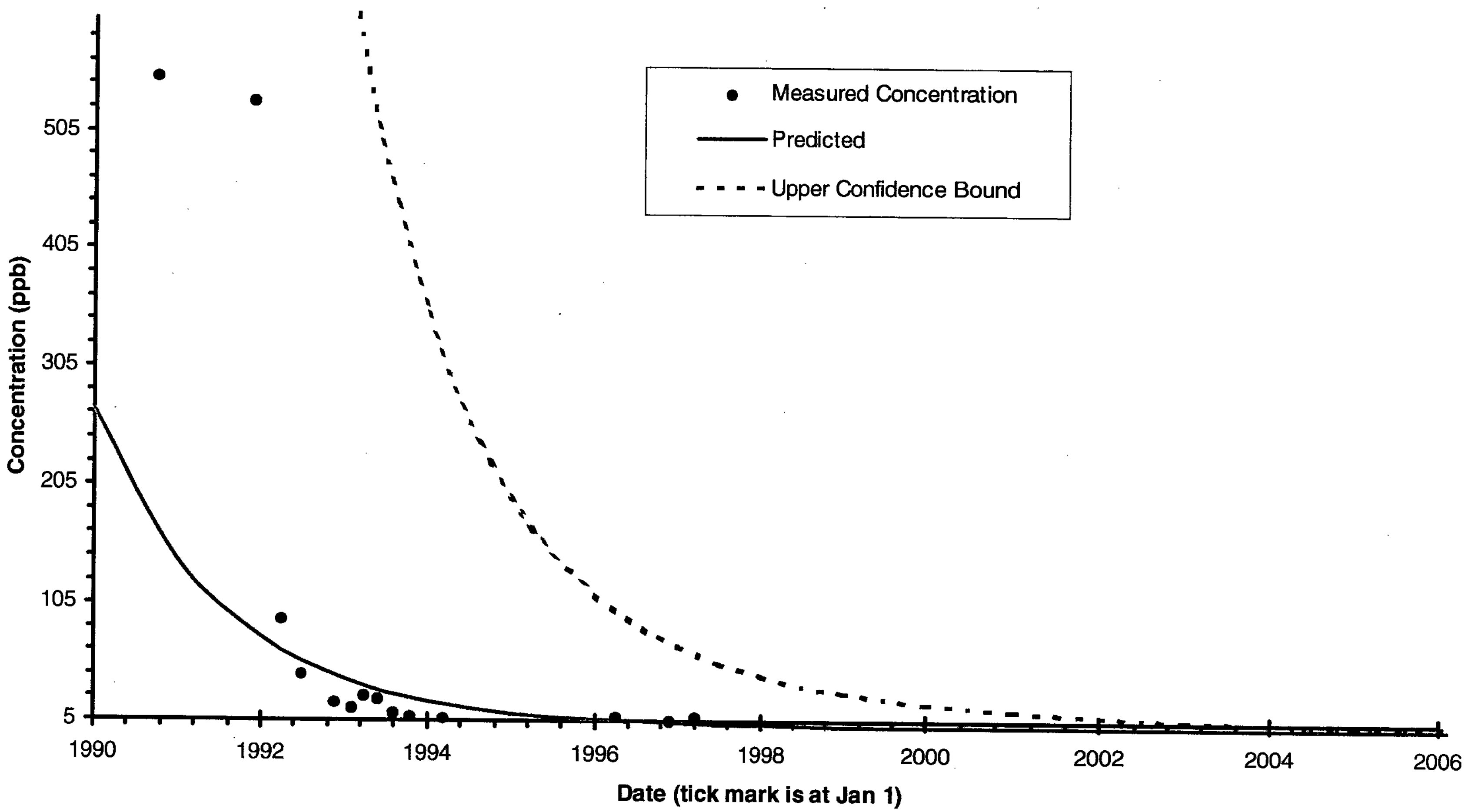
Predicted Concentration = exp(184.87 -0.0910*Year). Expected variation around the prediction is about +/- 74%. Based on 43 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 10. Observed and Predicted TCE Concentrations in Well HD-11, WPAFB



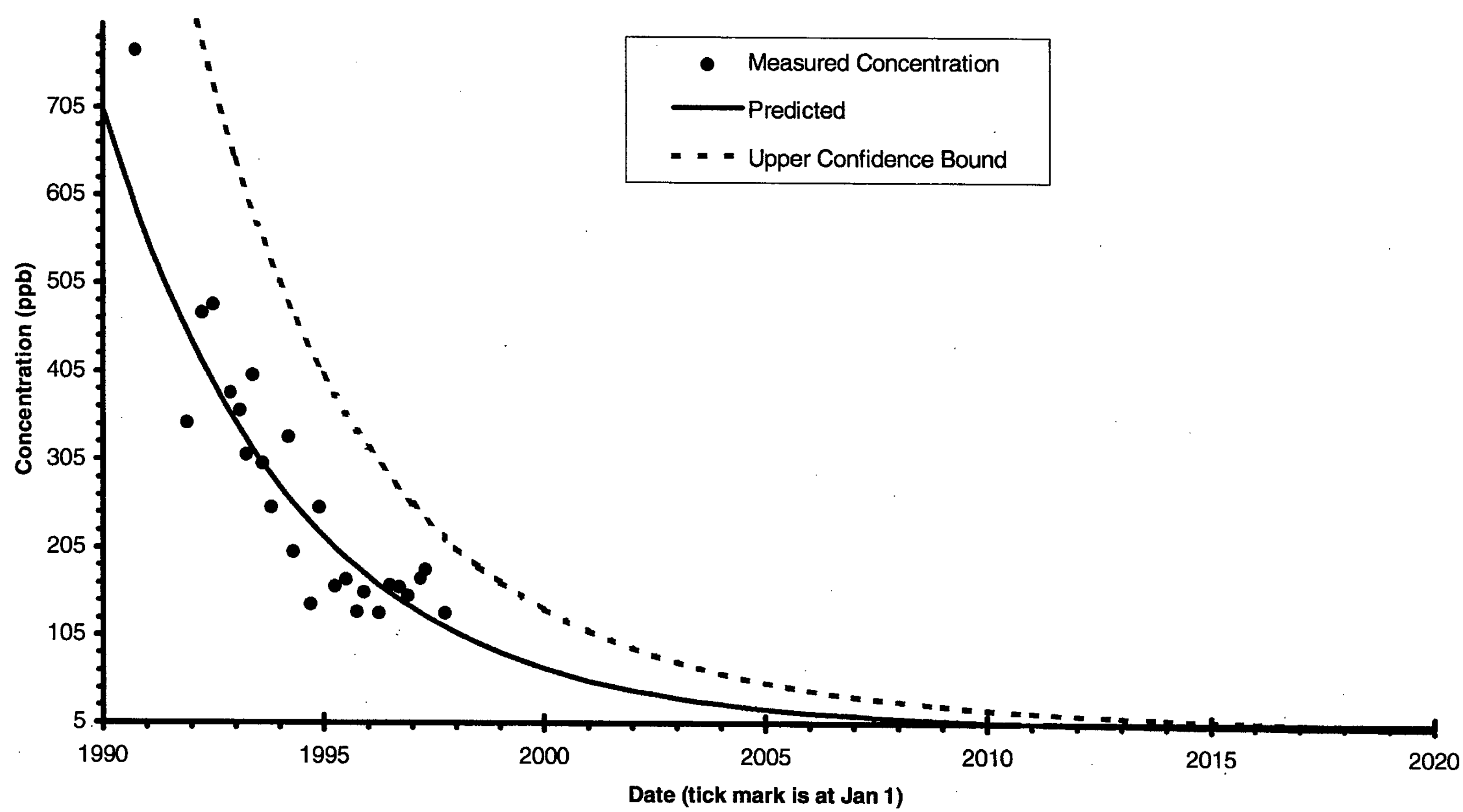
Predicted Concentration = exp(903.86 -0.4506*Year). Expected variation around the prediction is about +/- 43%. Based on 25 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 11. Observed and Predicted TCE Concentrations in Well CW5-55, WPAFB



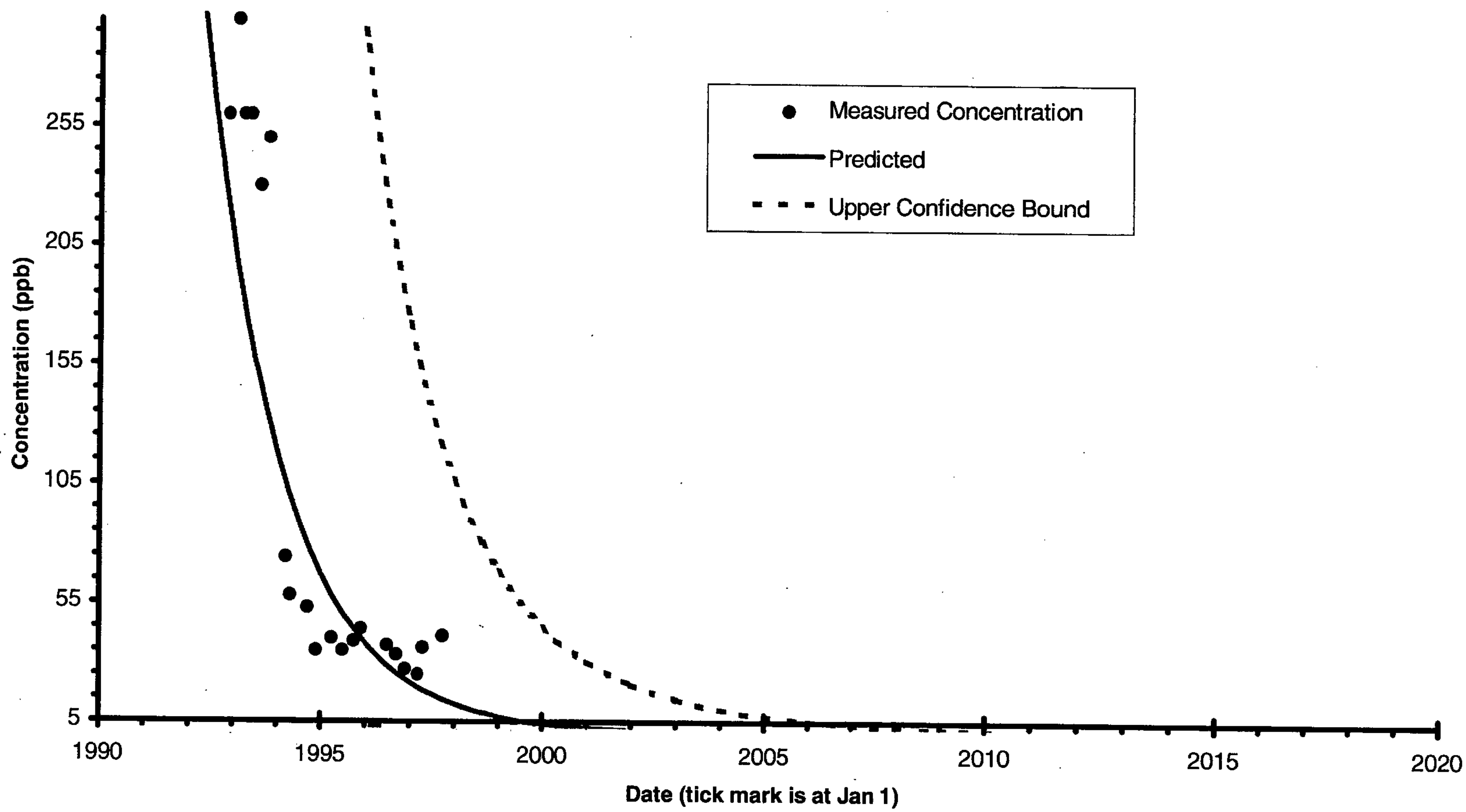
Predicted Concentration = exp(1274.50 -0.6376*Year). Expected variation around the prediction is about +/- 125%. Based on 14 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 12. Observed and Predicted TCE Concentrations in Well CW5-85, WPAFB



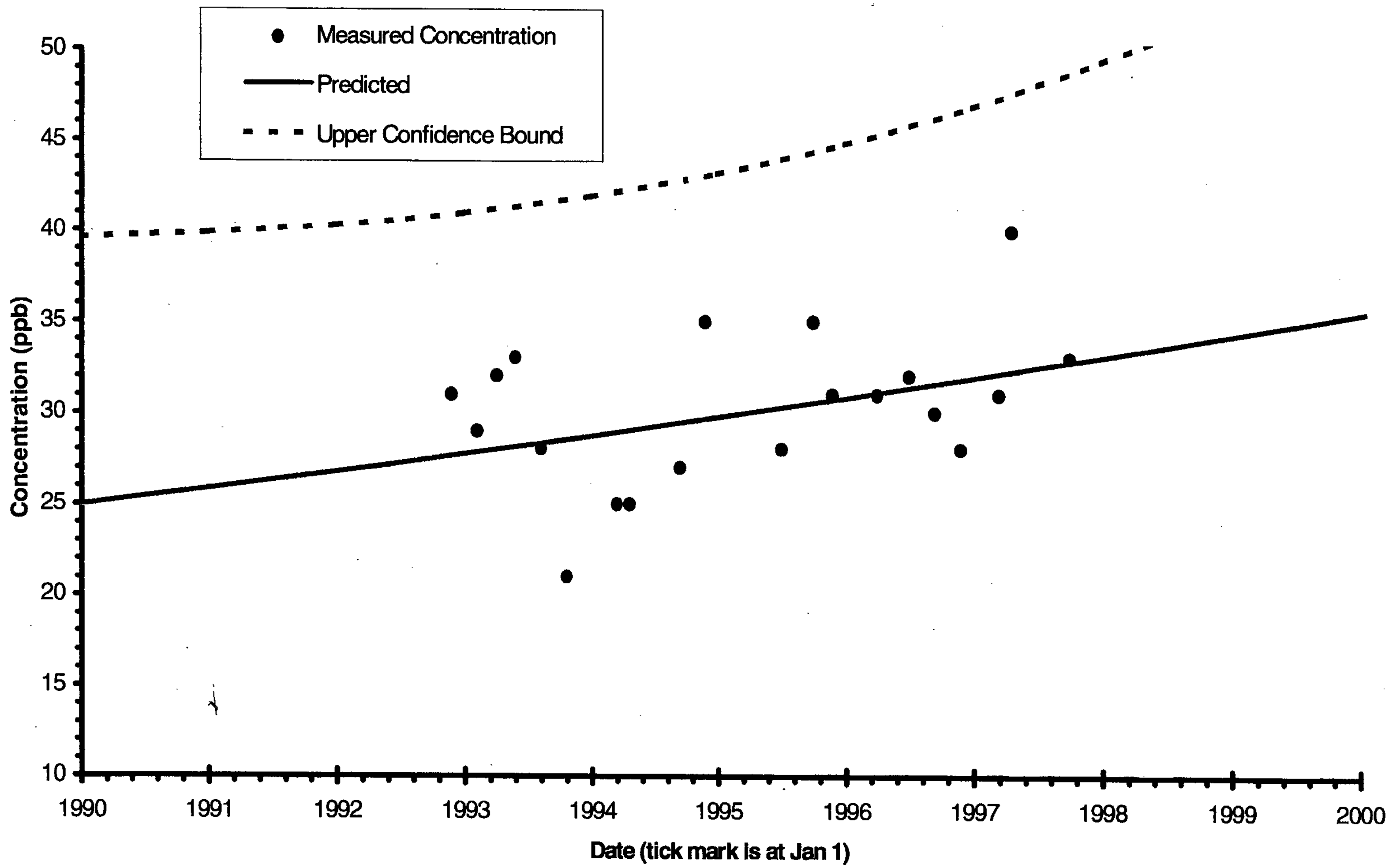
Predicted Concentration = exp(473.85 -0.2348*Year). Expected variation around the prediction is about +/- 29%. Based on 25 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 13. Observed and Predicted TCE Concentrations in Well MW-131M, WPAFB



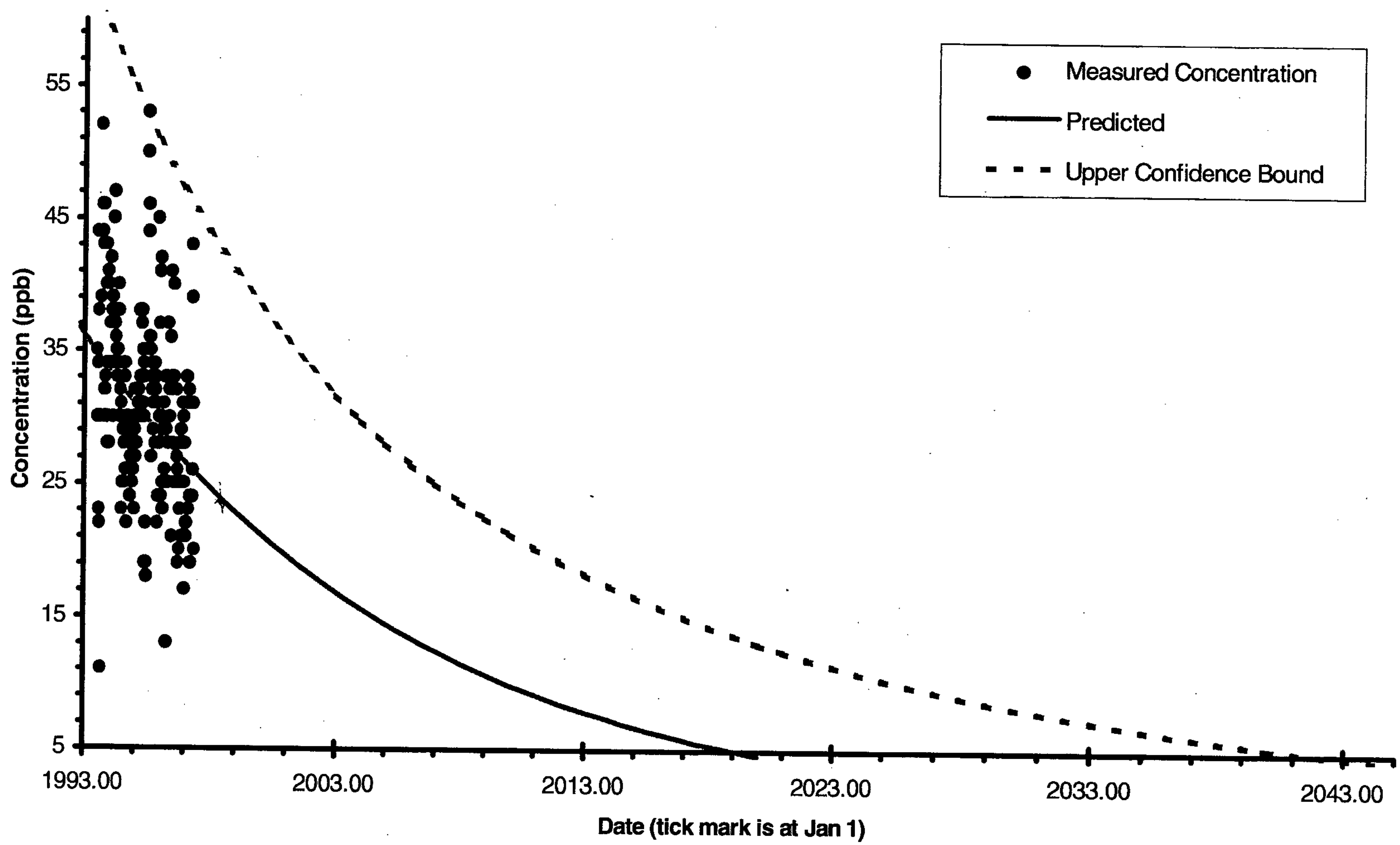
Predicted Concentration = exp(1138.92 -0.5688*Year). Expected variation around the prediction is about +/- 94%. Based on 21 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 14. Observed and Predicted TCE Concentrations in Well MW-132, WPAFB



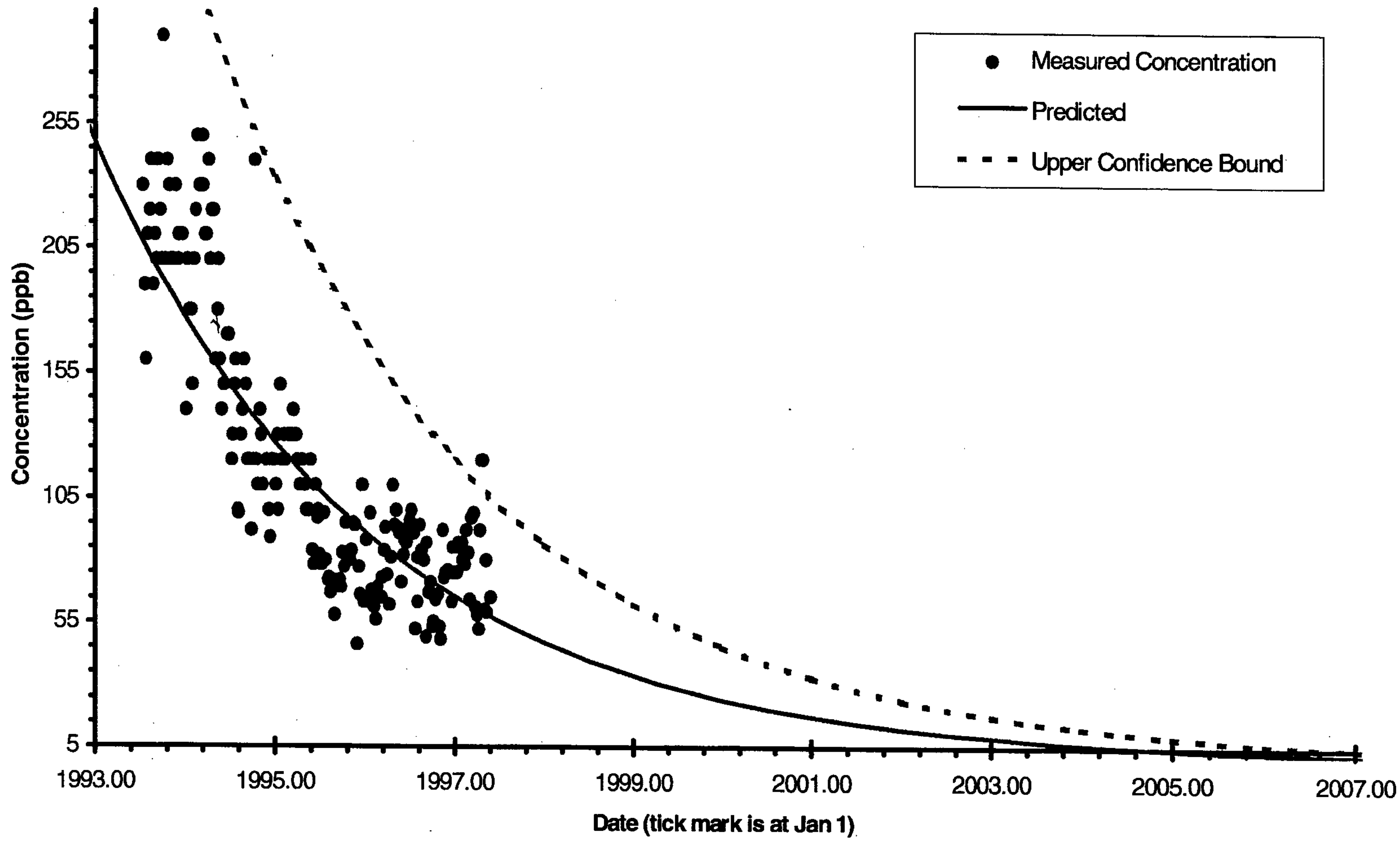
Predicted Concentration = exp(-66.93 + 0.0353*Year). Expected variation around the prediction is about +/- 17%. Based on 20 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 15. Observed and Predicted TCE Concentrations in Arrow St. Influent, Wurtsmith AFB



Predicted Concentration = exp(155.59 -0.0763*Year). Expected variation around the prediction is about +/- 29%. Based on 202 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.

Figure 16. Observed and Predicted TCE Concentrations in Mission St. Influent, Wurtsmith, AFB



Predicted Concentration = exp(668.90 -0.3329*Year). Expected variation around the prediction is about +/- 31%. Based on 200 measurements. Any conclusions may be sensitive to assumptions, including an assumption of exponential decay and a serial correlation of 0.4.